HYDROGEOLOGICAL STUDY
FINAL REPORT
PROPOSED SANITARY LANDFILL SITE
TOWNSHIP OF GLANBROOK
FOR
THE REGIONAL MUNICIPALITY
OF HAMILTON-WENTWORTH

GARTNER
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Gartner Lee Associates Limited

Consulting Engineering Geologists and Hydrogeologists

Toronto - Buttonville Airport ▪ Markham, Ontario ▪ L3P 3J9 ▪ 416-297-4600

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TOWNSHIP OF GLANBROOK
FOR
THE REGIONAL MUNICIPALITY
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PROJECT 76-49

JUNE 1978

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June 29, 1978.

The Department of Engineering,
The Regional Municipality of Hamilton Wentworth,
City Hall,
Hamilton, Ontario.

Attention: Mr. W. Wheten, P.Eng.
Commissioner of Engineering

Dear Sir:

Re: Hydrogeological Study
Final Report
Proposed Sanitary Landfill Site
Township of Glanbrook

We are pleased to submit our final hydrogeological report that deals with the above noted proposed landfill site located in Glanbrook as shown on the Key Map that follows.

This document discusses the existing hydrogeological setting of the lands of the subject property and assesses their suitability within this context for solid waste disposal. The report also provides guidelines and base data to assist the designers of the proposed facility for site development, operational and monitoring aspects. In this regard there has been an ongoing dialogue and discussion with Proctor & Redfern Limited during the study to facilitate their work. Data from our interim report (76-49), dated December 1976,are also incorporated.

For your convenience a summary follows the letter and Key Map at the beginning of the main text. Technical support data and maps are appended.

Continued ...

Mr. W. Wheten, P.Eng.
The Regional Municipality of
Hamilton Wentworth

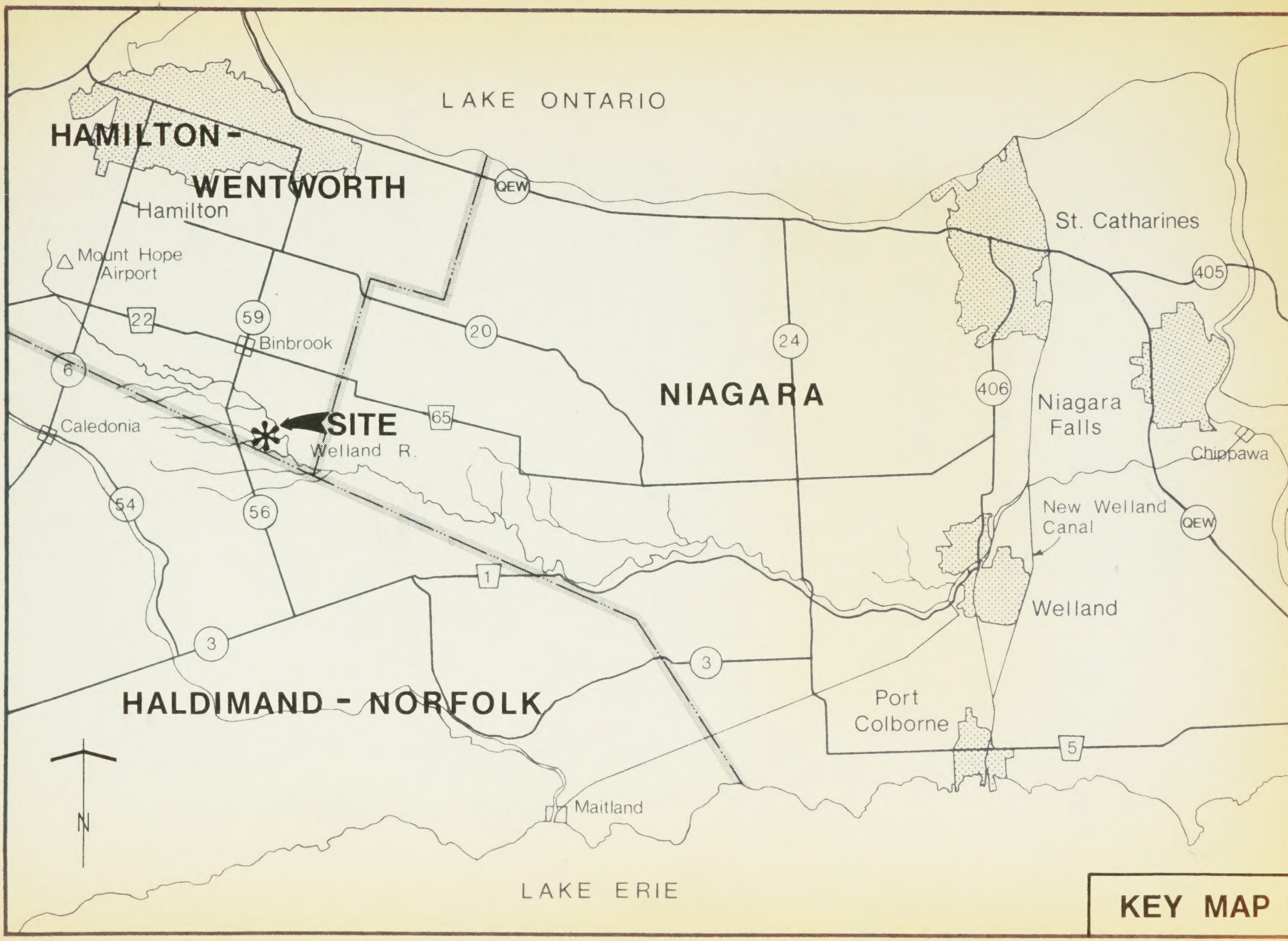
We wish to thank the Region for this opportunity to be of service on this most interesting project.

Respectfully submitted,

GARTNER LEE ASSOCIATES LIMITED

P.K. Lee, M.A.Sc., P.Eng.
Consulting Engineering Geologist.

PKL:jcm



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1·0 Summary & Conclusions

1.0 SUMMARY AND CONCLUSIONS

This report of our detailed hydrogeological assessment confirms earlier preliminary studies that the clay plain property is suitable for a sanitary landfill facility. The flood plain zones on the other hand must be isolated from the operation by set backs, berms and drainage provisions.

The site is underlain by very slowly permeable silty clay lacustrine soils with a fairly high water table. Ground water flows are very slow and are estimated to be in the hundredths of a foot per year range as based on permeability and hydraulic head measurements. Shallow ground water flow directions reflect the surface topography. Due to the high clay content, attenuation potential and long flow durations, we feel that ground water contamination of wells or base flow discharge to the surface waters is not a problem.

It will be necessary to properly engineer and construct facilities to safeguard surface water quality. In this regard we recommend that leachate collection systems be installed to prevent leachate springs at the landfill toes and mounding. Disposal of the collected leachate will have to be accommodated for and considered by others probably via sanitary sewer to a sewage treatment plant. Properly constructed berms, drainage swales and ditches will be needed. We have recommended siltation traps and sedimentation ponds to handle site runoff.

Gas migration from the waste does not present a problem because of the slowly permeable fine grained soils and fairly high water table.

Landfilling by use of cells 10-12 feet deep is anticipated Cell size should be based on the ability to complete filling in a 3 to 5 year period and thus minimize working and opened areas at any one time.

Workability and handling of the clay soils does present operational constraints especially in wet weather. Operational measures such as stockpiling, wise equipment

selection and use, control of cell base slopes and drainage etc. will be needed.

A ground and surface water monitoring program has been recommended. This will involve the installation of monitors as the program proceeds and should be located down gradient near the toe of the fill. These installations will monitor water in both the soils and the rock. Surface water quality would also be assessed at stations up gradient, adjacent to and downflow of the site in perennial waters. Selected domestic water wells should also be monitored.

We conclude then, based upon the findings of our study and analysis, that the subject property is suitable for a municipal solid waste disposal site from a hydrogeological viewpoint, provided that the facility is properly engineered and operated with the incorporation of the recommendations of this study.

2·0 Introduction

2. INTRODUCTION:

2.1 BACKGROUND:

Gartner Lee Associates Limited were retained by the Region of Hamilton Wentworth, Department of Engineering in 1976 to carry out a hydrogeological study. The subject lands, shown on the Key Map, were to be assessed with respect to their suitability for a sanitary landfill.

The overall study as originally proposed was modified when consent to enter onto private lands was refused. A series of boreholes and ground water monitors were placed on road right of ways. An analysis was then carried out using this and related data to produce an "interim" hydrogeological report, 76-49, in December 1976. This report was submitted for review by the Region, their Consultants and the Ministry of Environment. Monitoring and analysis of water levels was ongoing.

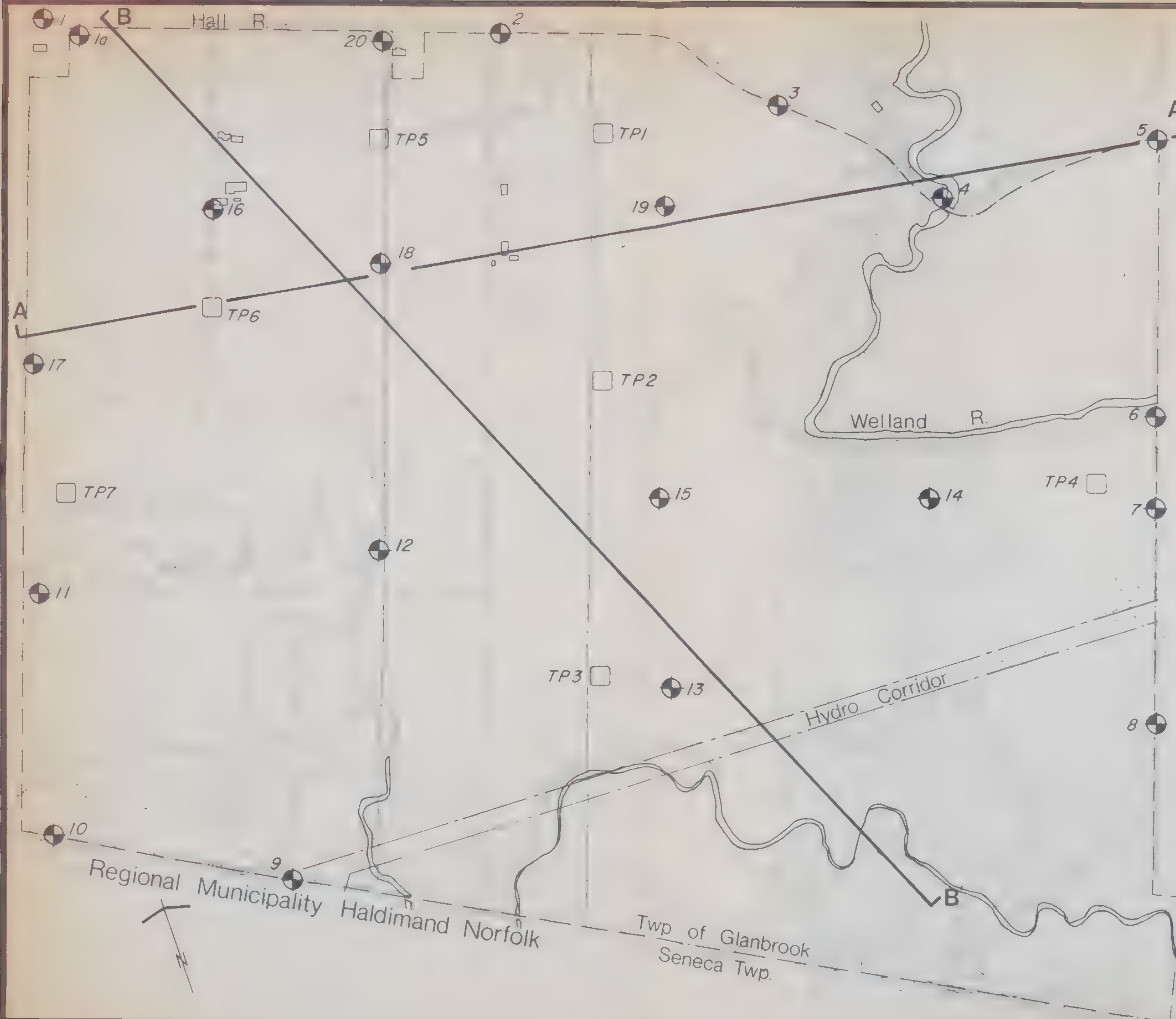
Subsequently, property access was obtained by the Region except for that of Mr. Druery located in the middle of the subject lands. A further detailed subsurface program, drilling, installing of monitors and testing was then carried out starting in December 1977.

Dialogue and informal transmission of information has been ongoing throughout the course of the study. This present report then ties together all of this information for review and use, especially for Hearing and Approvals purposes.

2.2 PURPOSE AND SCOPE:

The objectives of the study are

(i) To investigate the existing hydrogeologic setting of the subject lands and related environs.



Legend

12 Borehole Location and Designation

TP2 Test Pit Location and Designation

A — A′ Cross Section

Structure

— — Proposed Property Boundary

Site Plan

1

Hydrogeological Study

Proposed

Glanbrook Sanitary Landfill Site

for

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(ii) To assess the suitability of the subject lands from a hydrogeological point of view for a sanitary landfill operation

and

(iii) To provide base data to assist in the design and operations aspects.

This study will provide information for the Region their Consultants and the Ministry of the Environment in their review, design and approval tasks. This document will also serve as part of the Region's presentation in formal Hearings and public information meetings.

The scope of this report encompasses firstly the interpretation of the existing hydrogeological setting i.e., geology, soils, surface and ground water and water budget-use aspects. These base data are then used to evaluate the suitability of the site for landfilling and constraints to be dealt with in design and operation. Recommendations are provided to assist the designers in the development and operations aspects.

2.3 METHODOLOGY:

A preliminary study was completed and reported upon in December 1976, (Gartner Lee Associates Limited Report No. 76-49). This document was based upon data derived from boreholes (Nos. 1 to 10 inclusive) and monitors, placed in the road allowances around the site along with water well record data, airphoto interpretation techniques etc. Monitoring and analysis of water levels has been ongoing. These findings assisted in the present program setup and analysis.

In December 1977, access onto the subject lands was allowed except for the Druery property. Seven backhoe test pits were dug, in locations shown on Plate 1, "Site Plan". Excavations were carried to 15$\pm$ feet below grade and these were

logged by a hydrogeologist to obtain information on fracturing in the upper soil horizons, soil stratigraphy or layering, moisture relations, excavation and construction parameters. Details are provided in the Appendix, Part 1.

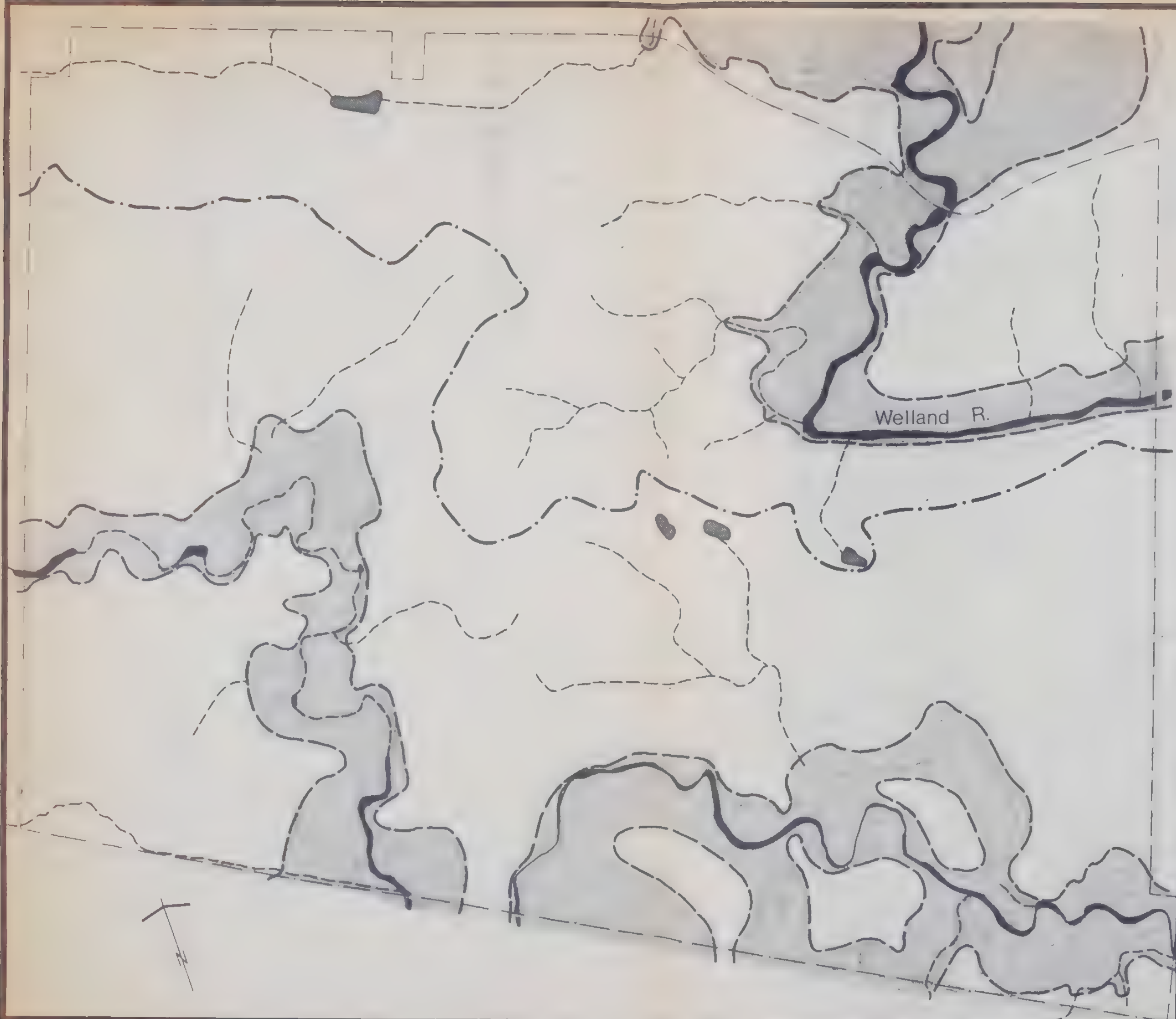
Following the test pit program, some 11 boreholes (numbers 1A and 11 to 20) were drilled during January and February 1978, at the locations shown on Plate 1. These test holes were drilled and split spoon samples retrieved in the soils down to the bedrock. Within the bedrock diamond drill techniques were used to recover continuous core samples. Piezometers which measure pressure at a point and standpipes which measure the free water surface were installed to create an 'observation nest' at each exploratory location. The ground elevations were supplied by survey staff of the Region. Details are contained in Part 1 of the Appendix.

Once the drilling was finished, the ground water monitors were developed by pumping to displace several volumes of water and allowed to respond. Water levels were measured about once a month. In situ slug tests were conducted on piezometers to measure the field permeability of the geologic materials. Details are provided in the Appendix, Part 2.

A comprehensive laboratory testing program was initiated to supplement the results provided in the interim report. Additional tests were conducted to determine gradation,permeability, cation exchange capacity and strength parameters.
See Part 1 of the Appendix for a summary of the testing results.

Once all the background data was gathered the hydrogeological, hydrological and water budget aspects of the proposed site were analyzed. Maps, cross sections and calculations were constructed. These data were then used to assess the feasibility of landfilling and to provide a basis for recommendations.

3·0 Hydrogeological Conditions



Legend

- Lacustrine Clay Plain
- Flood Plain
- Organic Slough
- Drainage Course
- Surface Drainage Divide
- Property Boundary

Physical Setting 2

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3.0 HYDROGEOLOGICAL SETTING:

3.1 Geology and Soils

Plate 2, 'Physical Setting" shows the surficial soil types, landforms and drainage on the subject property. The dominant landform is the gently undulating (0 to 2%) lacustrine clay plain, a regional scale physiographic unit. The next most dominant feature is the floodplain of the Welland River that cuts through the property. The floodplain corridors are bordered by well defined steep and wooded valley walls. A second but less pronounced floodplain, a tributary of the Welland also traverses the site. Other drainage is of a perennial or intermittent nature, usually flowing only during wet weather runoff periods or after high intensity storms.

The sequence of geologic materials encountered with depth is shown schematically below.

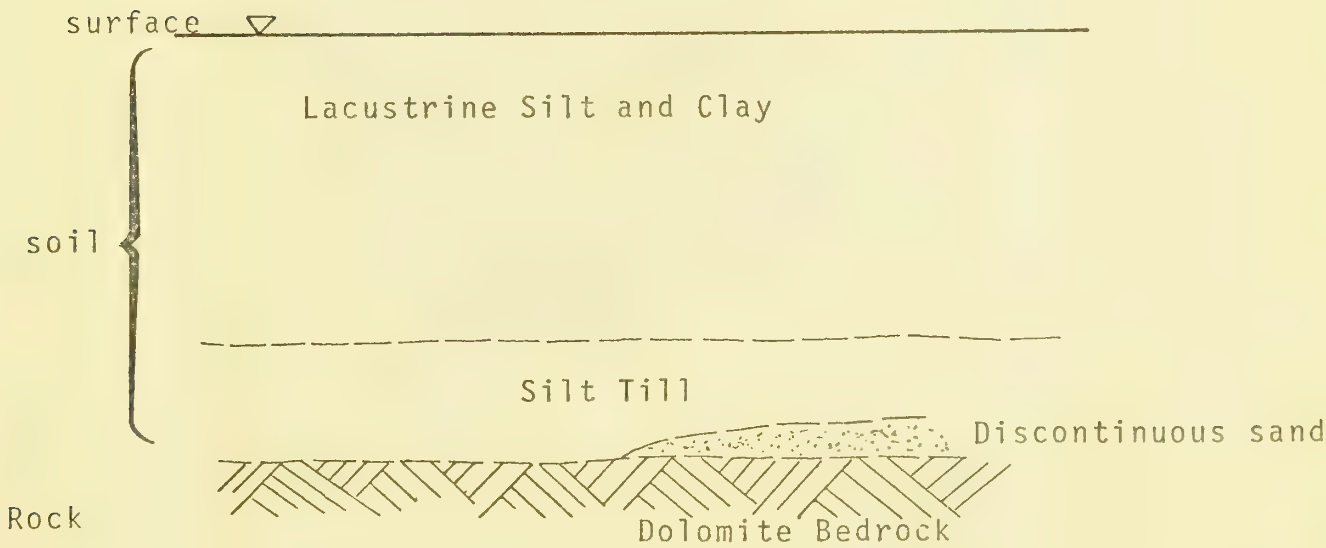


Plate 7, of Appendix Part 1, shows cross sections AA' and BB' to scale across the property. The soils vary in depth from 21 feet to 54.5 feet in thickness.

(i) The upper unit of soil in which landfilling will take place is a very slowly permeable lacustrine clayey silt to silty clay. This stratum was deposited in glacial times in waters of a lake that inundated the area. The unit is laminated to varved and extends from 15 to 50.5 feet below surface. The borehole logs in the Appendix, Part 1, provide details at each drilling location. The grain size envelope shown on Figure 1 of Part 1 of the Appendix indicates

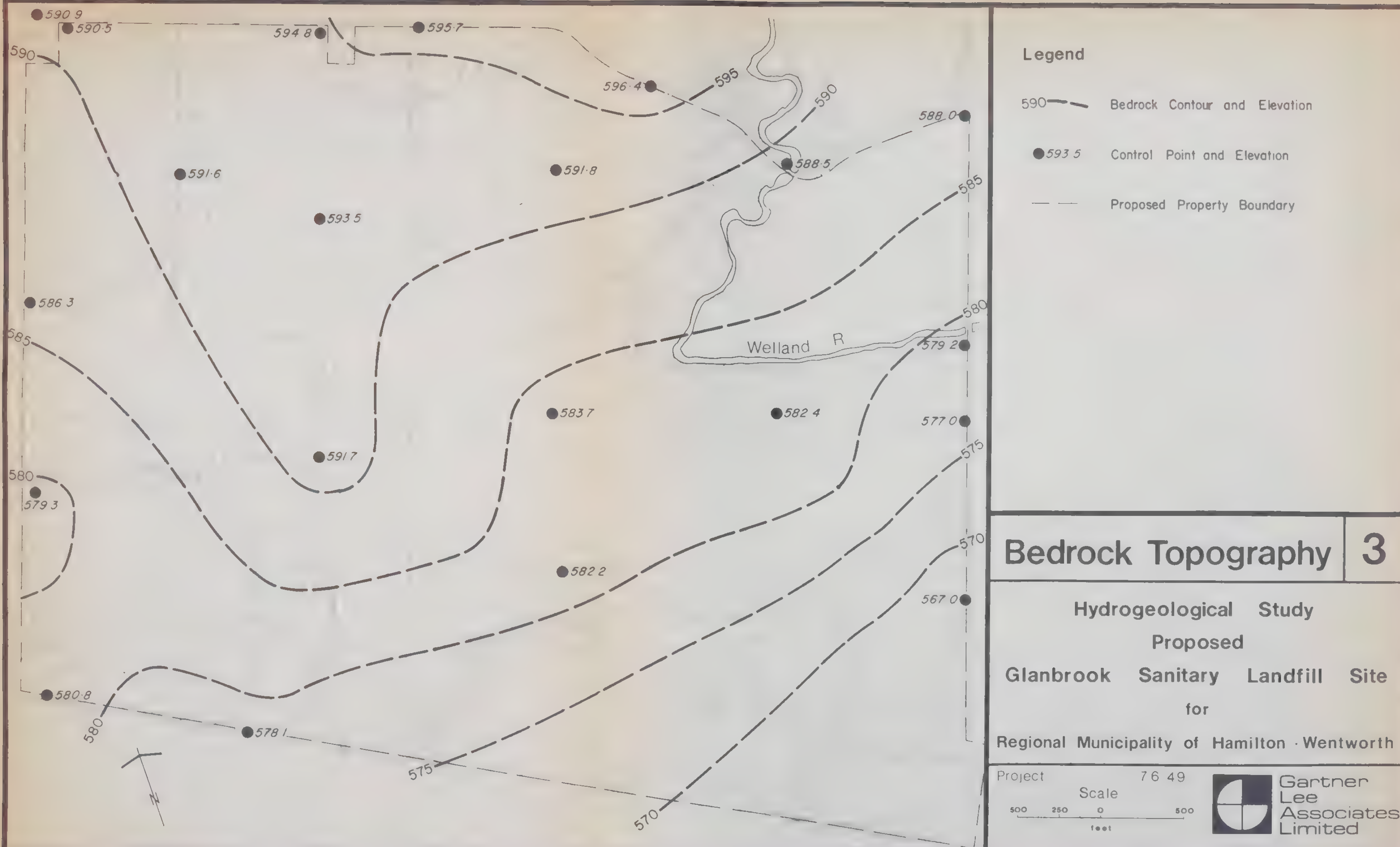
Sand 0 to 3%

Silt 26 to 89%

Clay 11 to 71%

Moisture contents of this soil insitu measured 17 to 47% with a trend increasing to depth and related to the zone of saturation. The liquid limits measured between 33 and 55% with a resulting mean average of 43%. Plastic limits averaged 23% and ranged between 20 and 28%. Details are shown on Table 1 appended. Undrained triaxial tests were carried out on selected samples and correlated with standard penetration 'N' values. Results on Table 2 indicate undrained shear strengths of 4.4 to 2.1 Kips per square foot. The total porosity of this unit is about 40%. The cation exchange capacity of the soil was measured at 11 to 52 milli-equivalents per 100 grams of soil. See Table 3 for details of the test results.

The permeabilities for this soil were measured at 10^{-7} cm/sec in the horizontal direction i.e. parallel to the bedding, and 10^{-8} cm/sec vertically. The laboratory permeabilities correlated well with the in situ slug tests. (See Tables 4 and 5 appended.) The backhoe test pits showed that the upper crust of these soils, i.e.



Bedrock Topography 3

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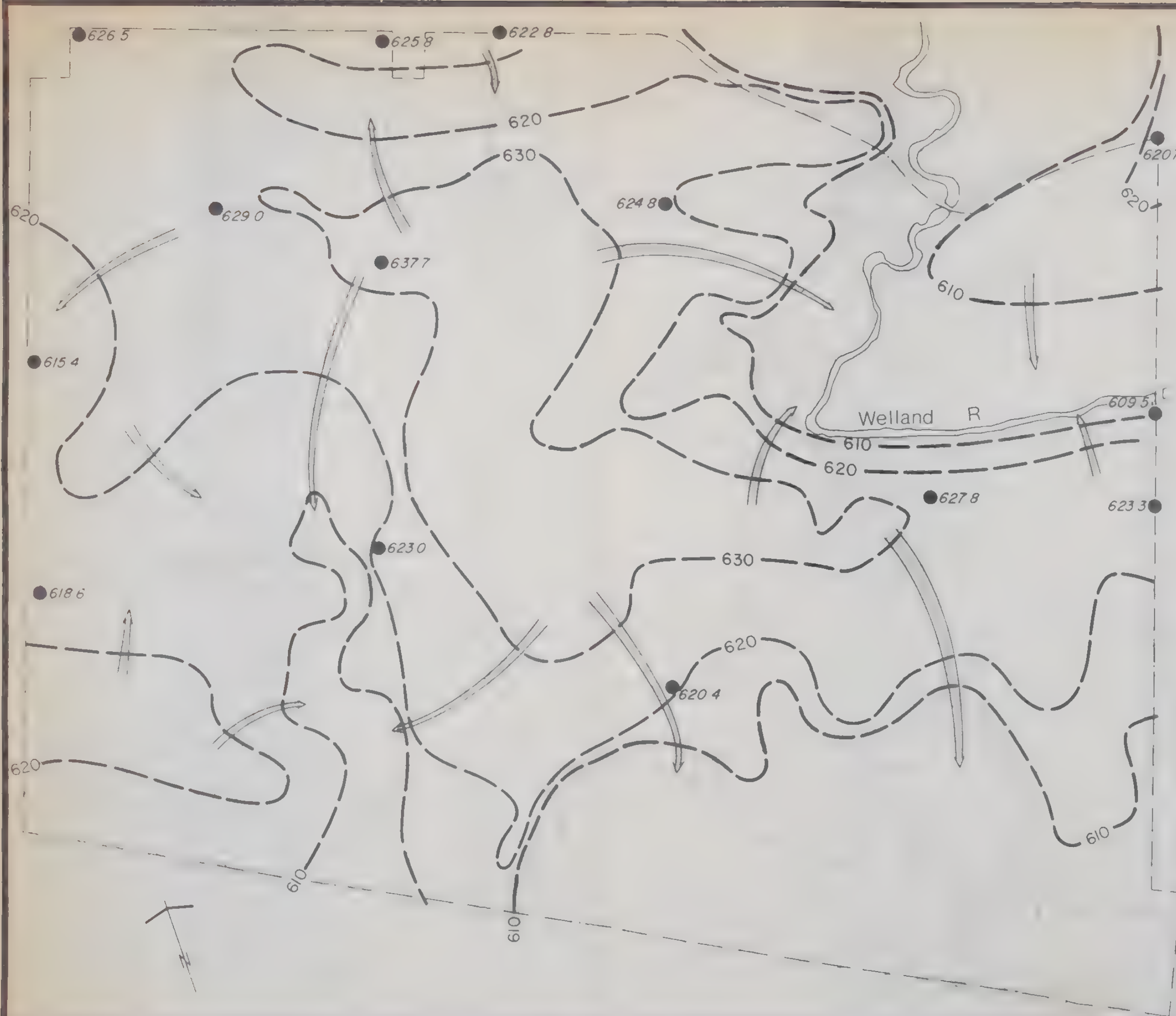
above the water table was dessicated and cracked. This surface fissuring due to wetting and drying and freeze, thaw, creates a secondary permeability in the soils, and tends to increase ground water flow within this zone.

(ii) The silt till soil unit located well below development levels, separates the upper layered unit from the bedrock. The typical gradation is shown on Figure 2 of Part 1 of the Appendix and indicates 29% gravel, 24% sand, 33% silt and 14% clay. Visual descriptions on the borehole logs indicate variations in texture. This unit is slowly permeable, in the 10^{-5} to 10^{-7} cm/sec range with a porosity of about 30%.

(iii) Thin discontinuous granular zones were found along the contact of the soil base and the underlying dolomite bedrock. These are sandy gravel to gravelly sand in texture and thus are permeable, in the range of 10^{-3} cm/sec with a porosity of about 35%. These buried sands are saturated and water bearing.

(iv) The dolomite bedrock of the Lockport Formation is the basement layer of the sequence for this study. The core recovered showed the rock to be massively bedded with fairly tight vertical joints, occasional shale partings and vugs. Slug tests in the field indicate a permeability of 10^{-6} to 10^{-7} cm/sec. Plate 3 shows an interpretation of the contours of the buried bedrock surface. Beds also dip fairly flatly to the south. This unit is the main drilled well aquifer in the area.



Legend

—610— Potentiometric Contour

Probable Ground Water Flow Direction (April, 1978)

● 637 7 Control and Elevation (April, 1978)

— — Proposed Property Boundary

Ground Water Regime
Water Table

4

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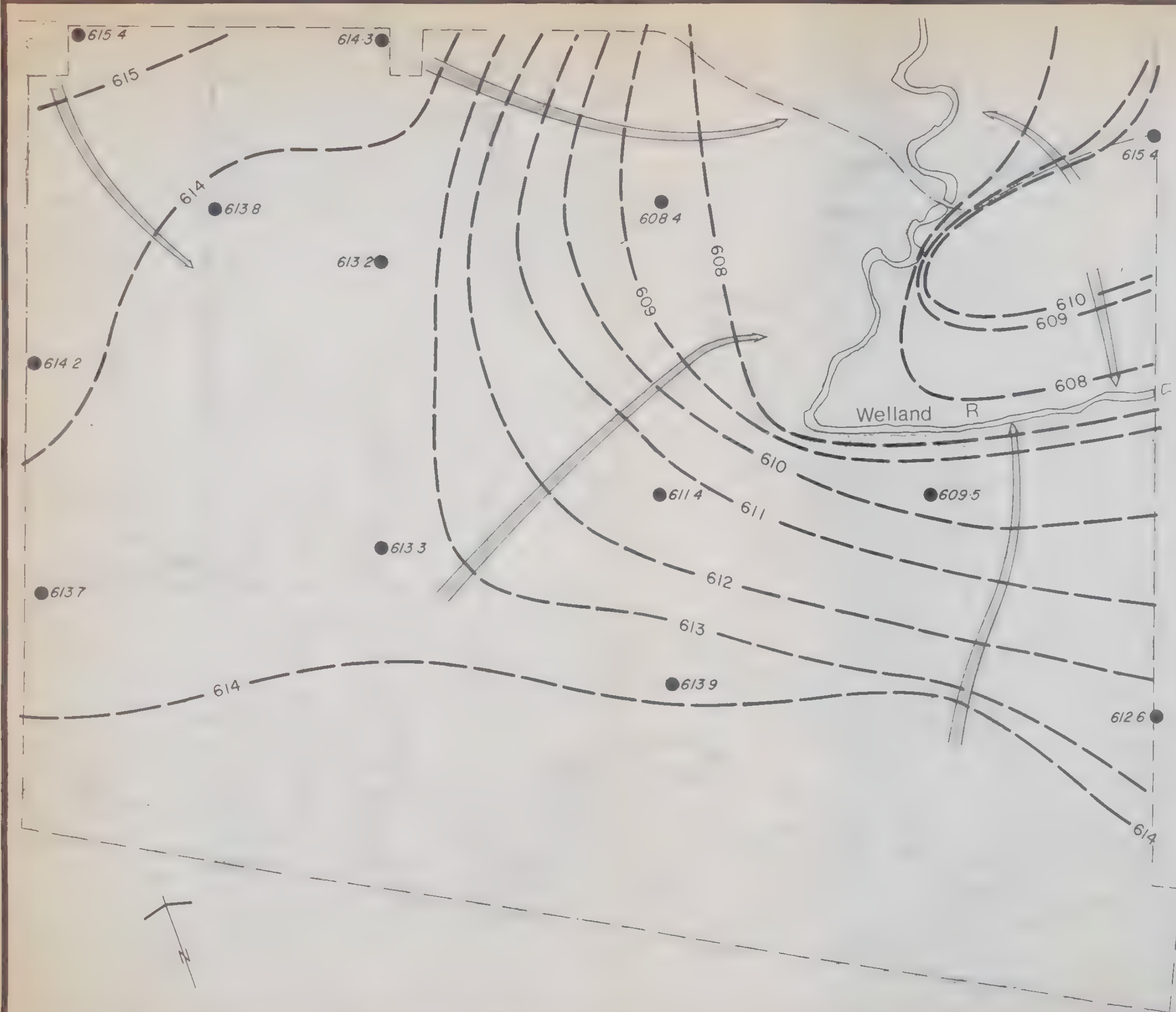

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—610— Piezometric Contour

Probable Ground Water Flow Direction (April, 1978)

●611·4 Control Point and Elevation (April, 1978)

— — Proposed Property Boundary

Ground Water Regime Bedrock

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3.2 Ground Water Aspects

The monitoring of the ground water network installed in the preliminary work i.e., on the road allowances, was begun in August 1976 and is ongoing. Levels in the boreholes within the property, i.e., 11 to 20 , were taken from February 14, 1978 onwards. Data taken on April 25, 1978, have been used to develop the maps and cross sections for discussions here. Monitoring of levels in all installations is ongoing.

Plate 4, illustrates our interpretation of the surface of the zone of saturation or the water table in April 25, 1978. A mound exists in the central area of the site and generally follows the height of land or topographic divide. The water table slopes toward and creates flow towards the flood plains where it tends to discharge. Therefore the perennialsurface drains receive recharge from the soils of the clay plain as well as water from surface runoff. The water table surface is a subtle reflection of the surface topography, 5 to 10' below grade.

Plate 5 shows the configuration of piezometric heads measured in the bedrock in April 1978. Note that flow occurs towards the valley of the Welland River. By superimposing Plates 4 and 5, it is apparent that piezometric heads in the rock on the southern property boundary are also higher than the water table. Therefore this surface drainage corridor is also a discharge zone creating flow from depth to surface.

Plate 8 shows two cross sections AA' and BB' that traverse the property. Arrows are used to show generalized flow directions of the ground water. When looking at these sections one must remember that there is an exaggeration of scale $^{400}/_{20}$ or 20:1. These sections further illustrate the downward or recharge gradients beneath the uplands and discharge or flow from depth in the flood plains. Refraction or bending of the flow lines at the soil/rock interface is also evident.

Hydrologic Setting 6

Fluctuations in the water table and the piezometric heads are recorded in Table 7 of the Appendix, Part 2. These are shown visually in the ground water hydrography Figures 3 to 6 inclusive in the same section of the Appendix. Fluctuations are an expression of infiltration of precipitation shown by the standpipes as mainly less than 5' in the water table. Heads at depth in the piezometers show similar trends as with the standpipes but with larger fluctuations and time lags.

Up to this point flow directions have been discussed and these are related to hydraulic head potentials. The velocity of flow of water through the void spaces of the subsurface units below the surface of saturation can be calculated using the expression

$$V = \frac{ki}{n}$$

where k = hydraulic conductivity

i = hydraulic gradient = $\frac{\text{head loss}}{\text{length of flow path}}$

and n = porosity

Flow velocities in the silty clay lacustrine soils are very slow. For example in the vicinity of borehole 18 where recharge is occurring, vertical flow is at a rate of .04 feet per year. Therefore water moving down to the rock under existing conditions takes about 1000 years to arrive there. Lateral flows are also very slow.

3.3 Surface Water

Figure 7 contained in Part 3 of the Appendix visually shows flows in the Welland River measured at a guaging station near Merritt's Church. Correlation with the climate data from Mount Hope airport for the same period shows the rapid response of this channel to precipitation. Periods of spring melt and wet fall periods illustrate the

large contribution of direct runoff from the clay plain soils. Fluctuations in flow varied between 450 cfs in flood periods to 5 cfs in summer drys. This low flow is probably an expression of base flow, i.e. the contribution of ground water discharge.

The patterns of drainage are illustrated on Plate 2. Two perennial channels traverse the site and the remainder of the overland flow is generally intermittent.

3.4 WATER WELLS

The location of water wells researched from records in the Ministry of the Environment files and by our staff in the field are shown on Plate 9 of Part 2 in the Appendix. Data obtained is summarized on Table 8 in the same section.

The majority of wells are developed from sources of supply in the bedrock or in sand and gravel seams just above and hydraulically connected to the rock. Some wells do tap random sand seams probably related to the till beneath the silty clay lacustrine surface soils. However, the bedrock is the best source in the area, and is the local aquifer. General flow trends in the bedrock are shown on Plate 5, in Section 3.2 preceding.

3.5 WATER BUDGET

Climate data are contained in Part 3 of the Appendix. Both 20 year normals and measured amounts from January 1, 1976 to January 1, 1978 are illustrated on Figure 8. Annual means for the area are in the 31 inch per year range with fairly even distribution.

During warm weather periods water is lost back

to the atmosphere from direction evaporation and evapotranspiration from vegetation. This has been calculated for the study period using the Thornthwaite method. Annual average potential evapotranspiration losses are in the 24 inch per year range with an August maximum.

Of the 31 inch precipitation, about 7 inches are available for infiltration into the ground for recharge and for surface runoff. Figure 10 illustrates the net gain and loss in the system. Water table fluctuations on the site of about 5'± indicate a recharge of about 3 inches annually. Most of this will occur in the spring period and a summer water deficiency will create a general decline in water levels.

4·0 Discussion & Recommendations

4.0 DISCUSSION AND RECOMMENDATIONS

4.1 General Comments and Site Suitability

All sanitary landfill sites produce two major pollutants, leachate and gas. Leachate is water that has contacted the refuse and has become contaminated with soluble compounds and gases derived from the decomposition process of the waste. This water is derived from the infiltration of precipitation, intercepted runoff and/or ground water. Bacterial decomposition of organic matter in the refuse produces gases: carbon dioxide, methane and hydrogen sulphide. The suitability and safety of any landfill site then requires a minimal impact from these leachates and gases. The hydrogeologic suitability is closely related to the potential impact. Results of the study show that the lacustrine silt and clay soils that landfilling will take place within have an excellent potential for the attenuation of leachate that might migrate with the flow of ground water. This is because of the fine grained texture, very long travel times, significant clay content and ion exchange capacity of these soils.

In such terrain, leachate poses more of a threat to surface water than to ground water. Landfilled refuse will be more permeable than the surrounding silts and clays. This would lead to a "bath tub" effect, i.e. a ground water mound builds up in the refuse buried within the cell. Eventually this action forms leachate springs where the water table reaches the ground surface. To mitigate this effect it will be necessary to collect enough leachate to prevent such springs and to dispose of this liquid with treatment say in a sanitary sewage system. As well, if small area cells are developed, these can be brought to completion and final covered in a shorter time to minimize infiltration of precipitation and thus leachate quantities produced. Details are provided in Section 4.2 that follows.

Gas movements from landfills occur through subsoils where these are permeable and porous, such as sands

and gravels, with a lower boundary being the water table. At the present site the slowly permeable silty clay soils and fairly high water table indicate that this is not a concern at this site. Venting of the cells should still be considered.

In summary then this site appears suitable except for floodplain areas from a hydrogeological point of view if properly engineered, constructed and operated. The recommendations and guidelines that follow are intended to optimize the facility from a hydrogeological viewpoint.

4.2 Leachate Aspects

As previously discussed, leachate collection at this site will likely only be necessary in the event that ground water mounding in the refuse is such that major leachate springs will occur at the toe of the landfill. Leachate flowing in the subsurface will have very slow, in the order of hundredths of a foot per year, travel times so that with attenuation mechanisms present water resources will be protected.

During the operation, precipitation entering the refuse will form leachate. These liquids will migrate vertically until they hit the water table and then will travel with the flow system.

If we assume that during the operation of the facility 12 to 18 inches infiltrate the waste, this will form leachate that will percolate to the bottom of the cell. The waste itself will absorb about 2 inches per cubic foot of refuse. The waste is estimated to have a porosity of 40 percent. Therefore each year the leachate level in the base of the cell will rise 30 to 45 inches.
For a 12 foot deep cell it would then take from 3 to 5 years to reach original grade and then create springs sometime after that. In order to stabilize this ground water mound it will be necessary to pump and collect leachate at the same

rate as recharge. If cells are kept to a size that they can be completed and covered in say less than 5 years then the final cover with vegetation can minimize infiltration quantities. With such a cover and reasonable slopes infiltration could then be limited to 4 to 6 inches per year. Such rates would then yield 0.2 to 0.3 gpm per acre of leachate to be collected to prevent springs and further mounding on the average. Ground water inflows will be very small due to the slow permeabilities of the clays.

The leachate collection system itself could be a perimeter system set in the wall of the cell, i.e. perforated pipe with a graded filter and gravity flow to collection points. Another alternative would be to place the collection system in the base of the cells before refuse placement. The base system could be used to manipulate leachate levels to any desired head. In any event such systems will have to be properly engineered and installed prior to landfilling.

The above leachate quantities are based on fairly severe rates. Such values can be lessened by good site management, filling and covering conservative but economic areas to final contours before proceeding to the next area.

Disposal of the leachate with some form of treatment will be needed but this is beyond the scope of our study and will be dealt with by others.

4.3 Gas Aspects

As discussed in Section 4.1, off site gas migration is not anticipated due to the hydrogeological setting. If surface drainage swales are left around the cells these will also create a positive cut off for gas migration. As a further measure the excavated cell should be checked for minor cracks or sand zones and if exposed these should be sealed off.

Once anaerobic conditions exist in the refuse the gases produced are often greater than 50 percent methane. Venting of this gas can be achieved by a "well" technique say perforated PVC pipe with a crushed stone bedding. This can be installed using a slip form technique as filling proceeds or by drilling at a later time or a combination thereof.

4.4 Other Development Aspects

As noted in Section 4.1 the site is suitable for landfilling except for floodplain zones. Proper setbacks from the valley walls will be required so that in situ barriers are left. Toe berms may be required in down slope areas especially.

Cells should be sized such that the operation can be completed in say 3 to 5 years to meet leachate aspects discussed earlier. We would recommend that excavations be carried into only the dense silty clays. The base should not extend to the softer zones at depth due to handling and related construction difficulties with these soft, sensitive subsoils. Cells would then be in the 10 to 12 foot depth range. The cells should be excavated by schedule such that working and opened areas are minimized at any one time. Consideration might be given to stripping of topsoil for reuse. The excavated subsoils could then be stockpiled for use as cover. Special treatment such as air drying may be needed in wet weather before use as cover. Locally in bad weather seasons some material may have to be wasted and clean fill imported. The excavation should be planned for summer periods.

Final Cover should be placed as soon as practical after completion of filling and seeded. Final contours should be at slopes probably not exceeding say 4:1. Daily cover will be a standard procedure.

Surface drainage provisions from the filled areas

should be accommodated for and taken to a siltation trap and sedimentation ponds before allowing discharge off site. Grading should be used to prevent inflow and runoff into cells possibly by perimeter swales and ditches properly designed and constructed. During wet weather surface water ponding in cells should be isolated from the fills say by a working berm in the initial floor filling stages. After confirmation of its uncontaminated state say by use of a conductivity measurement on site, this uncontaminated water could be discharged to the surface drainage swales.

Vehicle access will have to be designed for. On site access roads should be located such that they do not create runoff and gully erosion especially to valley wall areas. Proper protected runoff ditching should be accommodated for. Road base design on the silt tills will have to consider frost susceptible soils in some areas, and thus heavier design depths of granular base and sub-base. In the design stage a proper soils investigation will be needed along the chosen environment route.

Buildings constructed on the property will also require confirmation at their chosen location for bearing capacity and footing design from borehole data. At this time we see no problems for light loadings based on the shear strength of 2 to 4 kips per square foot(ksf).

Water supply for workers can be provided for with a drilled well in the building area. If placed near the southern zone of the property this may even be within discharge flow conditions. This should be properly constructed and tested to obtain a proper safe yield.

All boreholes within the fill areas should be overdrilled and grouted to seal potential access channels for leachate well before filling. In this regard the same procedure i.e. grouting should be used for any water wells or gas wells within the proposed cells. Close control and checking is mandatory in sealing boreholes and wells.

4.5 Monitoring Aspects

Monitoring facilities and programs for leachate in the cells, ground water beyond them, surface water and gas should be anticipated.

In conjunction with the leachate system, a simple riser pipe could be installed to check levels of leachate and to provide for samples to check qualities of leachate composition.

The ground water monitors beyond the cells can be left to check piezometric levels and quality as needed. We would recommend that further monitors properly cased, protected with caps and locks be established as nests in the soil and rock on the down flow gradient sides of the cells. These should be fairly close to the toe of the cells, say within 15 feet, placed prior to filling in the middle of any possible plume zone.

Background water quality should be established prior to landfilling in both the soils and the bedrock. This can be accomplished by two sets of tests on samples taken say 30 days apart. Installations should be properly developed and flushed.

A proper monitoring schedule should be set up in conjunction with Ministry of the Environment staff. We would anticipate that testing be restricted to indicators such as conductivity, chlorides - the most mobile ion, and say hardness. Full analysis on selected installations, especially the near cell monitors might be on an annual basis. The ongoing checking might be quarterly, related to seasonal climate patterns. These data should be analyzed by a hydrogeologist and transmitted for review by the Ministry of the Environment. Laboratory testing should be carried out by Ministry recommended facilities or by the Ministry of the Environment themselvcs and standard methods used.

To allay public concern domestic supply wells could also be considered in the monitoring program. These should be selected in conjunction with the Ministry of the Environment staff and public input. As with the other monitoring, background should be established prior to landfilling so that ongoing values can be compared to baseline data.

A surface water monitoring program should also be established with stations upstream from the landfill, adjacent to it and downstream especially in the perennial channels. As with ground water this should be on a pre-filling and on an ongoing basis carried out when ground water is checked. Sedimentation, siltation pond water should also be monitored.

Gas can be monitored in the installations described in Section 4.3 on a quarterly or semi annual basis.

If the site is approved the above program can be set up in consultation with the Ministry of the Environment. The data should be reviewed as received and the program may be modified as the operation proceeds.

5·0 Appendix

PART 1

GEOLOGIC DETAILS

BOREHOLE LOGS

LIST OF ABBREVIATIONS

PENETRATION RESISTANCE

Standard Penetration Resistance 'N' - The number of blows required to advance a standard split spoon sampler 12 inches into the sub-soil, driven by means of a 140 pound hammer falling freely a distance of 30 inches.

Dynamic Penetration Resistance - The number of blows required to advance a 2 inch, 60 degree cone, fitted to the end of drill rods, 12 inches into the sub-soil, the driving energy being 350 foot pounds per blow.

DESCRIPTION OF SOIL

The consistency of cohesive soils and the relative density or denseness of cohesionless soils are described as follows:

Consistency	'N' Blows/Foot	Denseness	'N' Blows/Foot
Very Soft	0-2	Very Loose	0-4
Soft	2-4	Loose	4-10
Firm	4-8	Compact	10-30
Stiff	8-15	Dense	30-50
Very Stiff	15-30	Very Dense	>50
Hard	>30		

M.W.T.P.L.	-	Much Wetter than Plastic Limit
W.T.P.L.	-	Wetter than Plastic Limit
D.T.P.L.	-	Drier than Plastic Limit
A.P.L.	-	About Plastic Limit

DESCRIPTION OF ROCK

$$\% \text{ Recovery} = \frac{\text{Total Length of Core Recovered/Run}}{\text{Total Length of Drilling Run}} \times 100$$

TYPE OF SAMPLE

SS	-	Split Spoon
AS	-	Auger Sample
RC	-	Rock Core
SC	-	Soil Core
ST	-	Shelby Tube (3" ø)

SYMBOLS

▲	-	Water Table Monitor (Standpipe Tip)
●	-	Piezometer Tip

BOREHOLE NO. 1

PROJECT NAME PROPOSED GLANBROOK LANDFILL SITE — PROJECT NO. 76-49

CLIENT REGIONAL MUNICIPALITY OF HAMILTON WENTWORTH — DATE August 12, 1976

BOREHOLE TYPE 3¼" I.D. Hollow Stem Augers — GEOLOGIST D.E.J.

ELEVATION 629.2 — TECHNOLOGIST L.L.

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
0.0'								
1.5'		TOPSOIL						
		LACUSTRINE SILT AND CLAY Grey brown changing to grey at 7' laminated clayey silt. W.T.P.L. Stiff	1	SS	10	26		
			2	SS	11	30		
26'								
		TILL Grey clayey silt till W.T.P.L. Stiff						
33'								
		SANDY GRAVEL Grey sandy gravel, saturated						
38.3'								
		BEDROCK Light grey crystalline dolomite mass.bedded,sound,local vugs & shale partings		RC				100% Recovery
44.5'								
		Borehole terminated in bedrock at 44.5'. On completion, borehole was open.						

● Piezometer Tip ▲ Standpipe Tip

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BOREHOLE NO. 1A

PROJECT NAME PROPOSED GLANBROOK LANDFILL SITE

PROJECT NO. 76-49

CLIENT REGIONAL MUNICIPALITY OF HAMILTON WENTWORTH

DATE January 5, 1978

BOREHOLE TYPE 3¼" I.D. Hollow Stem Augers, NX Core

GEOLOGIST D.E.J.

ELEVATION 627.3

TECHNOLOGIST A.H.

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
0.0'								
1.0		TOPSOIL						
		LACUSTRINE SILT & CLAY Brown clayey silt changing to grey silty clay at depth. W.T.P.L.						
32.5		TILL Grey sandy silt till, gravelly, saturated.						
36.8'		BEDROCK Light grey crystalline dolomite with occasional shale partings and small vugs. Vertical to sub-vertical fractures.	1	RC				89% Recovery
			2	RC				96% Recovery
			3	RC				96% Recovery
			4	RC				98% Recovery
			5	RC				100% Recovery
			6	RC				100% Recovery
			7	RC				100% Recovery
63.9'		Borehole terminated in bedrock at 63.9'.						

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 2

PROJECT NAME PROPOSED GLANBROOK LANDFILL SITE
PROJECT NO. 76-49
CLIENT REGIONAL MUNICIPALITY OF HAMILTON WENTWORTH
DATE August 11, 1976
BOREHOLE TYPE 3¼" I.D. HOLLOW STEM AUGERS
GEOLOGIST D.E.J.
ELEVATION 603.4'
TECHNOLOGIST L.L.

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
0.0'								
2.3'		TOPSOIL						
		LACUSTRINE SILT AND CLAY Brownish grey changing to grey at ± 15' clayey silt, odd laminae of silty clay, W.T.P.L. Stiff to very stiff	1	SS	18	37		
			2	SS	14	25	▲	
27'			3	SS	14	28	●	SAMPLE 3 Sand 1% Silt 55% Clay 44%
27.7'		TILL	4	SS	24	10		
		Refusal to augers at 27.7' Borehole terminated at 27.7' on assumed bedrock.						

● Piezometer Tip ▲ Standpipe Tip

BOREHOLE NO. 3

PROJECT NAME PROPOSED GLANBROOK LANDFILL SITE

CLIENT REGIONAL MUNICIPALITY OF HAMILTON WENTWORTH

BOREHOLE TYPE $3\frac{1}{4}$" I.D. HOLLOW STEM AUGERS

ELEVATION 624.4

PROJECT NO. 76-49

DATE August 11, 1976

GEOLOGIST D.E.J.

TECHNOLOGIST L.L.

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	TYPE	BLOWS/FT.	% WATER	GROUND WATER	REMARKS
0.0'								
1.5'		TOPSOIL						
		LACUSTRINE SILT AND CLAY Medium brown silt, saturated and loose	1	SS	9	29		SAMPLE 1 Sand 3% Silt 85% Clay 12%
		Changing at ± 17' to grey laminated clayey silt, W.T.P.L. Very stiff	2	SS	18	30		
26.5							▲	
28.0		TILL						
		BEDROCK Light grey crystalline dolomite massive bedded, sound local vugs and shale partings					●	
38.5								
		Borehole terminated at 38.5' in bedrock.		RC				83% recovery 9" shale bed from 30'0" - 30'9"

● Piezometer Tip ▲ Standpipe Tip

BOREHOLE NO. 4

PROJECT NAME PROPOSED GLANBROOK LANDFILL SITE
PROJECT NO. 76-49
CLIENT REGIONAL MUNICIPALITY OF HAMILTON WENTWORTH
DATE August 10, 1976
BOREHOLE TYPE 3¼" I.D. HOLLOW STEM AUGERS
GEOLOGIST D.E.J.
ELEVATION 609.5'
TECHNOLOGIST L.L.

DEPTH ELEV. 0.0'	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
1.0'		TOPSOIL						
		LACUSTRINE SILT AND CLAY Grey clayey silt W.T.P.L., stiff grit and pebbles from ± 10' layer of grey sandy clayey silt mixed with organic	1	SS	10	25		
16.5			2	SS	6	43		
21.0		TILL Grey sandy clayey silt till W.T.P.L., dense	3	SS	35	8		
		Refusal to augers at 21.0' Borehole terminated at 21.0' on assumed bedrock						

● Piezometer Tip ▲ Standpipe Tip

BOREHOLE NO. 5

PROJECT NAME: PROPOSED GLANBROOK LANDFILL SITE
PROJECT NO.: 76-49
CLIENT: REGIONAL MUNICIPALITY OF HAMILTON WENTWORTH
DATE: August 9, 1976
BOREHOLE TYPE: 3¼" I.D. HOLLOW STEM AUGERS
GEOLOGIST: D.E.J.
ELEVATION: 623.0
TECHNOLOGIST: L.L.

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	BLOWS/FT.	% WATER	GROUND WATER	REMARKS
0.0'								
1.0'		TOPSOIL						
		LACUSTRINE SILT AND CLAY Medium brown silt with rust fissures, saturated compact						
			1	SS	10	25		
		Changing at ± 18' to grey laminated clayey silt W.T.P.L. Stiff to very stiff	2	SS	21	27		
							Standpipe Tip	
			3	SS	10	36	Piezometer Tip	
33'								
35.0'		TILL						
		BEDROCK Brown stained crystalline dolomite slightly vuggy, shale partings changing at 38' to white limestone powder very soft		RC			Piezometer Tip	
				RC				
44.0'								
		Borehole terminated at 44.0' in bedrock.						

● Piezometer Tip ▲ Standpipe Tip

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BOREHOLE NO. 6

PROJECT NAME PROPOSED GLANBROOK LANDFILL SITE

PROJECT NO. 76-49

CLIENT REGIONAL MUNICIPALITY OF HAMILTON WENTWORTH

DATE August 9, 1976

BOREHOLE TYPE 3¼" I.D. HOLLOW STEM AUGERS

GEOLOGIST D.E.J.

ELEVATION 615.2'

TECHNOLOGIST L.L.

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	TYPE	BLOWS/FT.	% WATER	GROUND WATER	REMARKS
0.0'								
1.0'		TOPSOIL						
		LACUSTRINE SILT AND CLAY Grey brown interbedded silt and clayey silt W.T.P.L. very stiff	1	SS	16	20		
		Changing at ± 18' to grey laminated clayey silt W.T.P.L. Stiff	2	SS	10	37	▲	
							●	
			3	SS	13	37		
33'		TILL Grey clayey silt till W.T.P.L.	4	SS	70/1	32	●	
36.0'		Refusal to augers at 36.0' Borehole terminated at 36.0' on assumed bedrock						

● Piezometer Tip ▲ Standpipe Tip

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BOREHOLE NO. 7

PROJECT NAME PROPOSED GLANBROOK LANDFILL SITE — PROJECT NO. 76-49

CLIENT REGIONAL MUNICIPALITY OF HAMILTON WENTWORTH — DATE August 6, 1976

BOREHOLE TYPE 3¼" I.D. HOLLOW STEM AUGERS — GEOLOGIST D.E.J.

ELEVATION 624.3' — TECHNOLOGIST L.L.

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	TYPE	BLOWS/FT.	% WATER	GROUND WATER	REMARKS
0.0'		TOPSOIL						
0.5'		LACUSTRINE SILT AND CLAY Medium to grey brown clayey silt with rust fissures, varves of silty clay W.T.P.L. very stiff	1	SS	18	28		
			2	SS	17	27		
		Changing at ± 22' to grey silty clay W.T.P.L. stiff	3	SS	10	37	Standpipe Tip	SAMPLE 3 Sand 1% Silt 37% Clay 62%
							Piezometer Tip	
			4	SS	13	35		
42'		TILL Grey gravelly till, stony saturated	5	SS	47/9"	20	Piezometer Tip	
47.3'		Refusal to augers at 47.3' Borehole terminated at 47.3' on assumed bedrock.						

Piezometer Tip   Standpipe Tip

BOREHOLE NO. 8

PROJECT NAME: PROPOSED GLANBROOK LANDFILL SITE
PROJECT NO.: 76-49
CLIENT: REGIONAL MUNICIPALITY OF HAMILTON WENTWORTH
DATE: August 3, 1976
BOREHOLE TYPE: 3¼" I.D. HOLLOW STEM AUGERS
GEOLOGIST: D.E.J.
ELEVATION: 615.1'
TECHNOLOGIST: L.L.

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	TYPE	BLOWS/FT.	% WATER	GROUND WATER	REMARKS
0.0'								
0.5'		~~TOPSOIL~~						
		LACUSTRINE SILT AND CLAY Medium brown varved clayey silt with rust fissures W.P.T.L. stiff	1	SS	12	28		
		Changing at ± 18' to grey silty clay W.P.T.L. Firm to stiff	2	SS	9	36		
							Standpipe Tip	
			3	SS	7	25		
36'							Piezometer Tip	
		TILL Grey clayey silt till W.T.P.L. Very dense	4	SS	79	16		SAMPLE 4 Gravel 15% Sand 16% Silt 36% Clay 33%
48.1'								
		BEDROCK Light grey crystalline dolomite massive-bedded, shale parting. Upper 4.5' weathered, vuggy.		RC			Piezometer Tip	
56.3'		Borehole terminated at 56.3' in bedrock.						

● Piezometer Tip ▲ Standpipe Tip

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BOREHOLE NO. 9

PROJECT NAME PROPOSED GLANBROOK LANDFILL SITE
PROJECT NO. 76-49
CLIENT REGIONAL MUNICIPALITY OF HAMILTON WENTWORTH
DATE August 16, 1976
BOREHOLE TYPE 3¼" I.D. HOLLOW STEM AUGERS
GEOLOGIST D.E.J.
ELEVATION 612.1'
TECHNOLOGIST L.L.

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
0.0'								
1.5'		TOPSOIL						
		LACUSTRINE SILT AND CLAY Grey brown to brownish grey silty clay, laminated M.W.T.P.L. Soft	1	SS	2	44		
							Standpipe Tip	
			2	SS	3	42		SAMPLE 2 Sand 1% Silt 43% Clay 56%
25'								
29.5'		TILL Grey clayey silt till W.T.P.L. very stiff	3	SS	17	17	Piezometer Tip	
34.0'		SANDY GRAVEL						
36.0'		BEDROCK Light grey crys. dolomite						Artesian Water Pressure
		Borehole terminated at 36.0' in bedrock.						

● Piezometer Tip ▲ Standpipe Tip

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BOREHOLE NO. 10

PROJECT NAME PROPOSED GLANBROOK LANDFILL SITE — PROJECT NO. 76-49

CLIENT REGIONAL MUNICIPALITY OF HAMILTON WENTWORTH — DATE August 13, 1976

BOREHOLE TYPE 3¼" I.D. HOLLOM STEM AUGERS — GEOLOGIST D.E.J.

ELEVATION 613.9' — TECHNOLOGIST L.L.

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	TYPE	BLOWS/FT.	% WATER	GROUND WATER	REMARKS
0.0'		TOPSOIL						
0.5'		LACUSTRINE SILT AND CLAY Brownish grey changing to grey clayey silt W.T.P.L.						
15'		TILL Grey clayey silt till W.T.P.L. Very stiff Seam of clayey silt between 23' and 26'. Becoming sandy and reddish in colour from ± 29'	1	SS	19	26	▲	
			2	SS	17	21	●	
33.1		Refusal to augers at 33.1' Borehole terminated at 33.1' on assumed bedrock.						

● Piezometer Tip ▲ Standpipe Tip

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BOREHOLE NO. 11

PROJECT NAME PROPOSED GLANBROOK LANDFILL SITE
PROJECT NO. 76-49
CLIENT REGIONAL MUNICIPALITY OF HAMILTON WENTWORTH
DATE Jan. 17&18, 1978
BOREHOLE TYPE 4" O.D. SOLID STEM AUGER, NX CORE
GEOLOGIST D.E.J.
ELEVATION 622.3'
TECHNOLOGIST A.H.

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	TYPE	BLOWS/FT.	% WATER	GROUND WATER	REMARKS
0.0' – 1.0'		TOPSOIL						
1.0' – 27.5		LACUSTRINE SILT & CLAY Light brown laminated clayey silt - W.T.P.L. changing at 10.5' to grey laminated silty clay - M.W.T.P.L., firm-occasional clayey silt seams	1	SS	7	37	Standpipe Tip	
			2	SS	7	30		
27.5 – 36'		TILL Brownish grey clayey sandy silt till, gravelly, saturated, dense.	3	SS	25	11		
36' – 41'		LACUSTRINE SILT & CLAY W.T.P.L.					Piezometer Tip	
41' – 43'		SANDY GRAVEL - saturated	4	SS	32	30		
43' – 63.5'		BEDROCK Light grey crystalline dolomite with occasional shale partings, styolites and small vugs vertical fractures from 45.8 to 47.8 and 55.8 to 56.2	5	RC				98% Recovery
			6	RC				100% Recovery
							Piezometer Tip	
			7	RC				99% Recovery
			8	RC				98% Recovery
							Piezometer Tip	
63.5'		Borehole terminated in bedrock at 63.5'						

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 12

PROJECT NAME PROPOSED GLANBROOK LANDFILL SITE
PROJECT NO. 76-49
CLIENT REGIONAL MUNICIPALITY OF HAMILTON WENTWORTH
DATE Jan. 19&23, 1978
BOREHOLE TYPE 4" O.D. SOLID STEM AUGER, NX CORE
GEOLOGIST D.E.J.
ELEVATION 628.2'
TECHNOLOGIST A.H.

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	TYPE	BLOWS/FT.	% WATER	GROUND WATER	REMARKS
0.0'								
1.0'		TOPSOIL						
		LACUSTRINE SILT & CLAY Mottled brownish grey laminated clayey silt, fractured, A.P.L. becoming brown at 5.8' changing at 17.5' to grey silty clay - laminated, occasional saturated silt seam W.T.P.L., stiff	1	SS	28	25		
			2	ST				
			3	SS	12	26		
			4	SS	18	23		
							Standpipe Tip	
			5	SS	8	29		
			6	ST				
			7	SS	8	30		
36.5'			8	SS	15	32	Piezometer Tip	
		BEDROCK Light grey crystalline dolomite with occasional shale partings, styolites and small vugs.	9	RC				99% Recovery
			10	RC				99% Recovery
47.0'							Piezometer Tip	
		Borehole terminated in bedrock at 47.0'						

Piezometer Tip   Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 13

PROJECT NAME PROPOSED GLANBROOK LANDFILL SITE

PROJECT NO. 76-49

CLIENT REGIONAL MUNICIPALITY OF HAMILTON WENTWORTH

DATE Jan. 29&30, 1978

BOREHOLE TYPE 4" O.D. SOLID STEM AUGER, NX CORE

GEOLOGIST D.E.J.

ELEVATION 622.5'

TECHNOLOGIST A.H.

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
0.0'								
1.3'		TOPSOIL						
		LACUSTRINE SILT & CLAY Mottled brownish grey clayey silt changing at 6' to brown laminated silt, saturated changing at 12' to grey laminated silty clay, W.T.P.L., stiff	1	SS	10	25		dessicated to 6'
			2	SS	8	34		
20.0'								
		TILL Brown sandy silt till with occasional pockets of sand and large boulders saturated	3	AS				
			4	SC				
			5	SC				
40.3'								
		BEDROCK Light grey crystalline dolomite with occasional thin shale partings, styolites and small vugs.	6	RC				100% Recovery
			7	RC				100% Recovery
			8	RC				100% Recovery
			9	RC				100% Recovery
			10	RC				100% Recovery
61.8'			11	RC				100% Recovery
		Borehole terminated in bedrock at 61.8'						

Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 14

PROJECT NAME PROPOSED GLANBROOK LANDFILL SITE
PROJECT NO. 76-49

CLIENT REGIONAL MUNICIPALITY OF HAMILTON WENTWORTH
DATE Jan. 31 & FEB. 1/78

BOREHOLE TYPE 4" O.D. SOLID STEM AUGER, NX CORE
GEOLOGIST D.E.J.

ELEVATION 636.9'
TECHNOLOGIST A.H.

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
0.0'								
1.3'		TOPSOIL						
		LACUSTRINE SILT & CLAY						
		Mottled, brownish grey changing at 4' to brown laminated clayey silt-occasional sub-vertical fractures.	1	SS	42	23		dessicated to 4'
		A.P.L.	2	ST				
		very stiff	3	SS	29	26		
		changing at 27.5' to grey laminated silty clay with occasional red brown silt inclusion	4	SS	21	28		
		M.W.T.P.L.	5	SS	16	26		
		firm to stiff						
			6	ST				
			7	SS	9	29		
			8	SS	7	38		
			9	SS	9	33		
50.5		TILL	10	SS	31	24		
54.5		Brown sandy till - bouldery						
		BEDROCK Light grey crystalline dolomite with occasional shale partings, small vugs and sub-vertical fractures.	11	RC				98% Recovery
			12	RC				100% Recovery
64.7								
		Borehole terminated in bedrock at 64.7'						

Piezometer Tip Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 15

PROJECT NAME PROPOSED GLANBROOK LANDFILL SITE

PROJECT NO. 76-49

CLIENT REGIONAL MUNICIPALITY OF HAMILTON WENTWORTH

DATE Jan. 28&29, 1978

BOREHOLE TYPE 4" O.D. SOLID STEM AUGER, NX CORE

GEOLOGIST D.E.J.

ELEVATION 638.7'

TECHNOLOGIST A. H.

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	TYPE	BLOWS/FT.	% WATER	GROUND WATER	REMARKS
0.0' – 1.3'		TOPSOIL						
		LACUSTRINE SILT & CLAY Mottled brownish grey changing to brown at 5.8' clayey silt, laminated, occasional sub-vertical fractures, W.T.P.L., very stiff	1	SS	32	21		dessicated to 6'
			2	SS	15	29		
			3	SS	15	30		
		changing at 27.5' to grey laminated silty clay with occasional small inclusions of red brown silt W.T.P.L. very stiff to stiff	4	SS	19	25		
			5	SS	23	17	Standpipe Tip	
			6	SS	8	31	Piezometer Tip	
38			7	SS	10	34		
42.5		TILL Brownish grey sandy silt till, saturated.	8	SS	15	12		
47.5		LACUSTRINE SILT & CLAY	9	SS	23	28		
55'		TILL Brownish grey sandy silt till, saturated, very dense.	10	SS	100	6		
		BEDROCK Light grey crystalline dolomite with occasional thin shale partings, styolites and small vugs.	11	RC				96% Recovery
65.3'			12	RC			Piezometer Tip	100% Recovery
		Borehole terminated in bedrock at 65.3'						

Piezometer Tip   Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 16

PROJECT NAME PROPOSED GLANBROOK LANDFILL SITE

PROJECT NO. 76-49

CLIENT REGIONAL MUNICIPALITY OF HAMILTON WENTWORTH

DATE Jan. 13, 1978

BOREHOLE TYPE 4" O.D. SOLID STEM AUGER, NX CORE

GEOLOGIST D.E.J.

ELEVATION 636.0'

TECHNOLOGIST A.H.

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
0.0'								
1.0'		TOPSOIL						
		LACUSTRINE SILT & CLAY Mottled brown changing at 5.5' to brown laminated clayey silt, silt partings, occasional fractures, A.P.L., very stiff	1	SS	31	25		
			2	SS	26	24		
			3	SS	27	20		
			4	SS	12	25		SAMPLE 6
		Changing at 22' to grey laminated silty clay with occasional inclusions of red brown silt, M.W.T.P.L., Stiff	5	SS	11	31	▲	Sand 1% Silt 30% Clay 69%
			6	SS	9	35		
			7	SS	13	31		SAMPLE 8
39.5'							●	Gravel 29% Sand 24% Silt 33% Clay 14%
		TILL Brown sandy silt till, saturated	8	SS	89	11		100% Recovery
44.4'		BEDROCK Light grey crystalline dolomite with occasional shale partings, small vugs and sub-vertical fractures.	9	RC				
			10	RC				94% Recovery
54.0'							●	
		Borehole terminated in bedrock at 54.0'						

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 17

PROJECT NAME PROPOSED GLANBROOK LANDFILL SITE — PROJECT NO. 76-49

CLIENT REGIONAL MUNICIPALITY OF HAMILTON WENTWORTH — DATE January 16, 1978

BOREHOLE TYPE 4" O.D. Solid Stem Auger, NX Core — GEOLOGIST D.E.J.

ELEVATION 618.8 — TECHNOLOGIST A.H.

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	TYPE	BLOWS/FT.	% WATER	GROUND WATER	REMARKS
0.0								
1.3		TOPSOIL						
		LACUSTRINE SILT & CLAY Mottled brownish grey changing at 5.5' to brown clayey silt, laminated, W.T.P.L. firm changing at 10' to grey laminated silty clay with occasional laminations of red brown clayey silt MWTPL, firm	1	SS	6	27		Fractured to 6'
			2	SS	4	37		
			3	SS	4	39	▲	
			4	SS	6	36		
25.2			5	SS	8	9		
		TILL Brownish grey clayey sandy silt till, saturated, WTPL					● ●	
32.5			6	SS	31	11		
		BEDROCK Light grey crystalline dolomite with occasional shale partings, styolites & small vugs, sound.	7	RC				100% Recovery
			8	RC				100% Recovery
42.3								
		Borehole terminated in bedrock at 42.3'						

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 18

PROJECT NAME PROPOSED GLANBROOK LANDFILL SITE — PROJECT NO. 76-49

CLIENT REGIONAL MUNICIPALITY OF HAMILTON WENTWORTH — DATE January 24, 1978

BOREHOLE TYPE 4" O.D. Hollow Stem Auger, NX Core — GEOLOGIST D.E.J.

ELEVATION 641.0 — TECHNOLOGIST A.H.

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	TYPE	BLOWS/FT.	% WATER	GROUND WATER	REMARKS
0.0								
1.2		TOPSOIL						
		LACUSTRINE SILT & CLAY						
		Mottled brownish grey changing to brown silty clay, laminated, APL, very stiff	1	SS	21	21		Occasional fractures in upper layers
			2	ST				Sample 2 Sand 1% Silt 44% Clay 55%
			3	SS	21	23		
		changing at 22' to grey laminated silty clay, occasional clayey silt seams and small inclusions of red brown silt WTPL, stiff	4	SS	28	25	Standpipe Tip	
			6	ST				
			7	SS	11	28		
			8	SS	13	28	Piezometer Tip	
45'								
47.5		TILL						
		BEDROCK Light grey crystalline dolomite with occasional shale portions, styolites & small vugs	9	RC				95% Recovery
			10	RC			Piezometer Tip	100% Recovery
55.7								
		Borehole terminated in bedrock at 55.7'						

Piezometer Tip   Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 19

PROJECT NAME: PROPOSED GLANBROOK LANDFILL SITE — PROJECT NO. 76-49

CLIENT: REGIONAL MUNICIPALITY OF HAMILTON WENTWORTH — DATE: Jan. 25&27, 1978

BOREHOLE TYPE: 4" O.D. SOLID STEM AUGER, NX CORE — GEOLOGIST: D.E.J.

ELEVATION: 627.9' — TECHNOLOGIST: A.H.

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	TYPE	BLOWS/FT.	% WATER	GROUND WATER	REMARKS
0.0'								
1.3'		TOPSOIL						
		LACUSTRINE SILT & CLAY Mottled brown changing at 5.5' to brown laminated silty clay A.P.L., stiff	1	SS	17	24		fractures to 6'
		changing at 16.3' to grey silty clay laminated, silt varves, W.T.P.L., stiff	2	SS	10	28		
26.3			3	SS	10	29		
36.1		TILL Brownish grey clayey sandy silt till, occasional sand pockets, saturated, very dense.	4	SS	65			
		BEDROCK Light grey crystalline dolomite with occasional shale partings styolites, small vugs and vertical fractures.	5	RC				100% Recovery
			6	RC				
			7	RC				100% Recovery
			8	RC				100% Recovery
			9	RC				100% Recovery
58.3			10	RC				100% Recovery
		Borehole terminated in bedrock at 58.3'						

Piezometer Tip — Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 20

PROJECT NAME PROPOSED GLANBROOK LANDFILL SITE
CLIENT REGIONAL MUNICIPALITY OF HAMILTON WENTWORTH
BOREHOLE TYPE $3\frac{1}{4}$" I.D. HOLLOW STEM AUGER, NX CORE
ELEVATION 629.6'

PROJECT NO. 76-49
DATE Jan. 4, 1978
GEOLOGIST D.E.J.
TECHNOLOGIST A.H.

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	TYPE	BLOWS/FT.	% WATER	GROUND WATER	REMARKS
0.0'								
1.5'		TOPSOIL						
		LACUSTRINE SILT & CLAY Mottled brownish grey changing to brown at 5.5' clayey silt, laminated occasional vertical fractures and thin silt seams, W.T.P.L., Stiff	1	SS	18	33		dessicated to 6'
			2	SS	10	29		
			3	SS	5	34		
			4	SS	5	40		
		Changing at 15.5' to grey laminated silty clay, M.W.T.P.L. firm.	5	SS	7	34		
31'		TILL Red brown sandy silt till	6	SS	10	47		
34.8'		BEDROCK Light grey crystalline dolomite with occasional shale partings and small vugs.	7	RC				95% Recovery
			8	RC				88% Recovery
45.7'		Borehole terminated in bedrock at 45.7'						

Piezometer Tip   Standpipe Tip

Gartner Lee Associates Limited

TEST PIT RESULTS

TEST PIT 1

0' - 1'	Topsoil
1' - 2.5'	Brownish grey silty clay, W.T.P.L. leached horizon, vertical and horizontal fractures, blocky structure
2.5' - 6'	Grey brown clayey silt, W.T.P.L. horizontally bedded; horizontal and sub-vertical fractures seepage in fractures
6' - 15'	Grey silty clay - W.T.P.L. becoming M.W.T.P. with depth, horizontally bedded
	Dry and open on completion.

TEST PIT 2

0' - 0.6'	Topsoil
0.6' - 4'	Mottled brownish grey silty clay, W.T.P.L. friable, blocky structure, horizontal and sub-vertical fractures
4' - 13'	Grey brown clayey silt, W.T.P.L. silt seams up to 0.2' thick; seepage from silt seams, some vertical fracturing
	Dry and open on completion

TEST PIT 3

0' - 1'	Topsoil
1' - 6'	Brownish grey clayey silt, W.T.P.L. friable, blocky structure; primary vertical fractures with secondary horizontal fractures, some seepage through fractures
6' - 11'	Brownish grey clayey silt, W.T.P.L. laminated, occasional silt seams (0.3' thick), sub-vertical bedding, oxidized zones along bedding
	Dry and open on completion.

TEST PIT 4

0' - 0.6'	Topsoil
0.6' - 2'	Brown to light brown silty clay, W.T.P.L. leached horizon; friable, dessicated; heavily fractured
2' - 13'	Grey brown clayey silt, W.T.P.L. laminated - laminations increase with depth; vertical fractures predominate, minor horizontal fracturing; occasional silt seam - waterbearing

Dry and open on completion

TEST PIT 5

0' - 1.3'	Topsoil
1.3' - 3.1'	Brown silty clay - W.T.P.L. mottled; friable, blocky structure, seepage along fractures
3.1' - 5'	Brown clayey silt - W.T.P.L. mottled; friable, blocky structure; fractured
5' - 7.5'	Brown silt - saturated
7.5' - 9'	Brown silt, saturated laminated, minor clay varves
9' - 11'	Grey brown clayey silt - M.W.T.P.L. laminated

Dry and open on completion

12 hours later, 0.5 feet water in bottom of pit.

TEST PIT 6

0'	- 0.6'	Topsoil
0.6'	- 2.2'	Brown to light brown silty clay - W.T.P.L. mottled; friable, heavily fractured
2.2'	- 12'	Brownish grey clayey silt - W.T.P.L. heavily fractured giving blocky structure; occasional silt zones - seepage; vertical fractures dominate creating unstable faces

Dry and open on completion

12 hours later, 1 foot water in bottom of pit, considerable cave of pit walls.

TEST PIT 7

0'	- 1'	Topsoil
1'	- 3.2'	Brown silty clay becoming darker brown to grey brown at ± 2 feet, W.T.P.L. mottled; friable; blocky structure
3.2'	- 3.7'	Light brown clayey silt - W.T.P.L.
3.7'	- 11'	Brown to grey brown clayey silt - W.T.P.L. laminated; heavily fractured; seepage at 10 feet.

Dry and open on completion

12 hours later, 0.5 feet water in bottom of pit, minor caving.

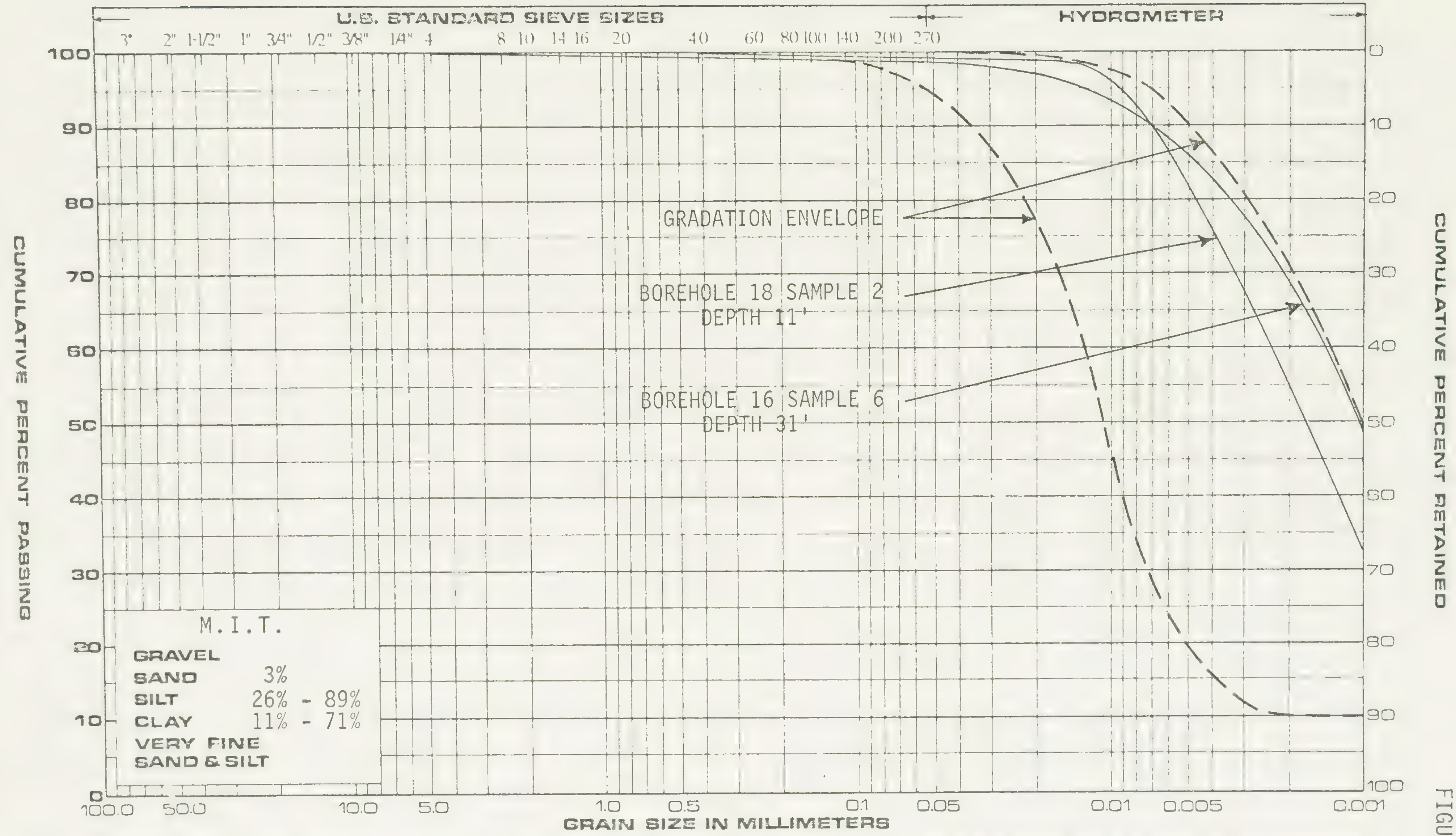
LABORATORY AND FIELD

TEST RESULTS

Gartner Lee Associates Limited

PARTICLE SIZE DISTRIBUTION

FIGURE 1.



UNIFIED	GRAVEL	SAND: COARSE	SAND: MEDIUM	SAND: FINE	SILT & CLAY					
M.I.T.	STONES	GRAVEL	SAND: COARSE	SAND: MEDIUM	SAND: FINE	SILT: COARSE	SILT: MEDIUM	SILT: FINE	CLAY	
U.S. BUREAU	GRAVEL	SAND: COARSE	SAND: MED.	SAND: FINE	SAND: V. FINE	SILT	CLAY			

JOB NAME PROPOSED GLANBROOK LANDFILL SITE JOB NO. 76-49 HOLE NO. ______ SAMPLE NO. ______

DEPTH ______ REMARKS GRADATION ENVELOPE (BASED ON 6 SAMPLES) - LACUSTRINE SILT AND CLAY

PARTICLE SIZE DISTRIBUTION

FIGURE 2.

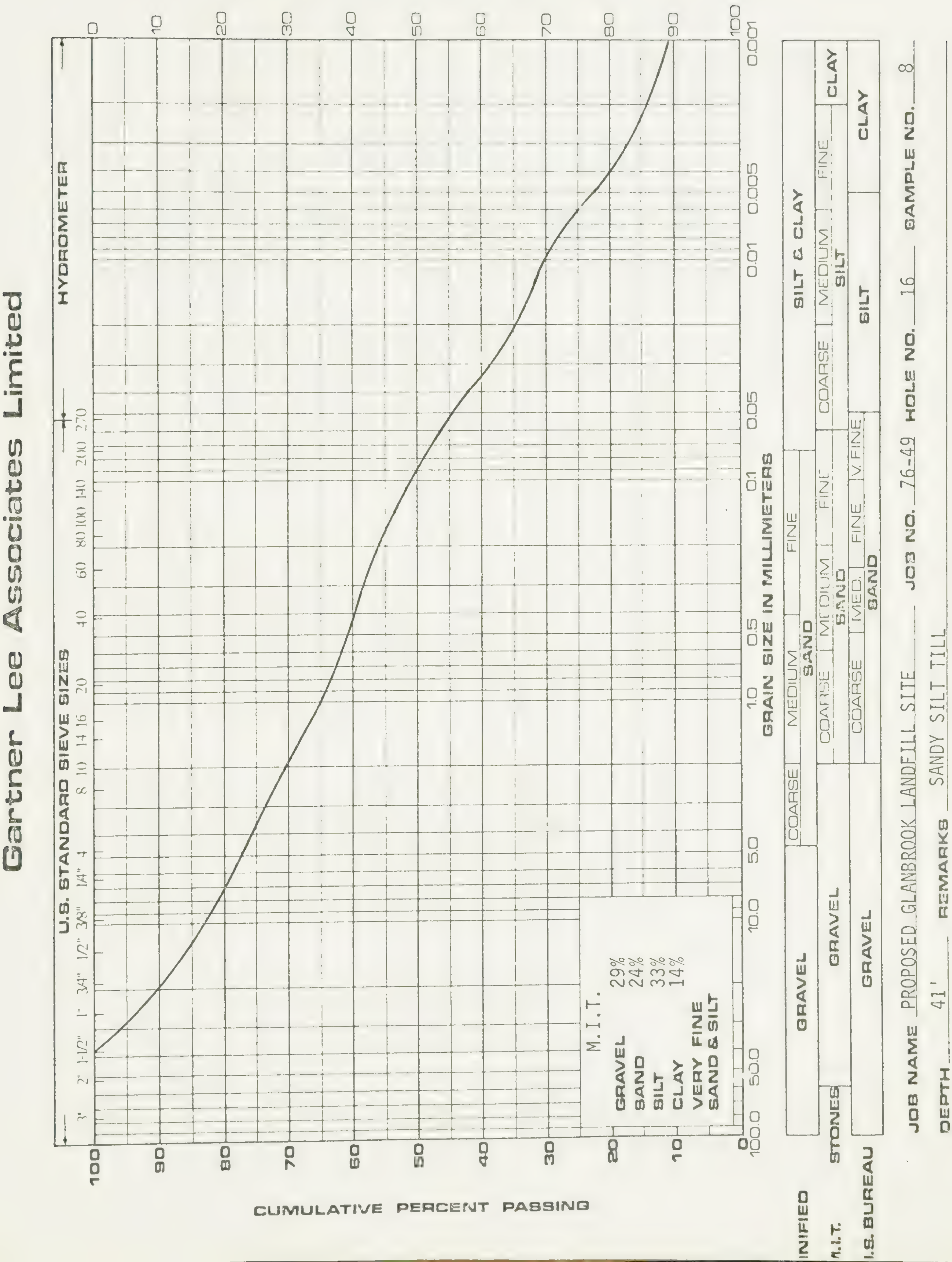


TABLE 1

ATTERBERG LIMITS TEST RESULTS

Borehole No.	Sample No.	Depth (ft.)	Liquid Limit(%)	Plastic Limit(%)	In Situ Moisture	Classification
2	3	24	34	20	33	Clayey Silt -W.T.P.L.
3	1	9	33	22	29	Clayey Silt -W.T.P.L.
7	3	29	54	20	38	Silty Clay -W.T.P.L.
8	4	39	34	20	19	Clayey Silt -A.P.L.
9	2	19	55	28	41	Silty Clay -W.T.P.L.
18	1	6	42	25	21	Clayey Silt -A.P.L.
18	2	10	40	25	28	Silty Clay -W.T.P.L.
18	7	36	49	25	28	Silty Clay -W.T.P.L.
19	1	6	49	24	24	Silty Clay -A.P.L.

TABLE 2

QUICK UNDRAINED TRIAXIAL RESULTS

Borehole No.	Sample No.	Depth (ft.)	Shear Strength(c) (psf)	Axial Strain(%)	Unit Weight (pcf)	Water Content(%)
18	2	11.5	4,400	4	127	26
18	6	30	2,100	2.5	119	33

TABLE 3

CATION EXCHANGE RESULTS

Borehole No.	Sample No.	Depth (ft.)	Cation Exchange Capacity(me/100 gm)*
15	6	31	52
18	1	6	11
18	7	36	29

* me/100 gm = milli-equivalents per 100 grams of soil

TABLE 4

CONSTANT HEAD PERMEABILITY TEST RESULTS

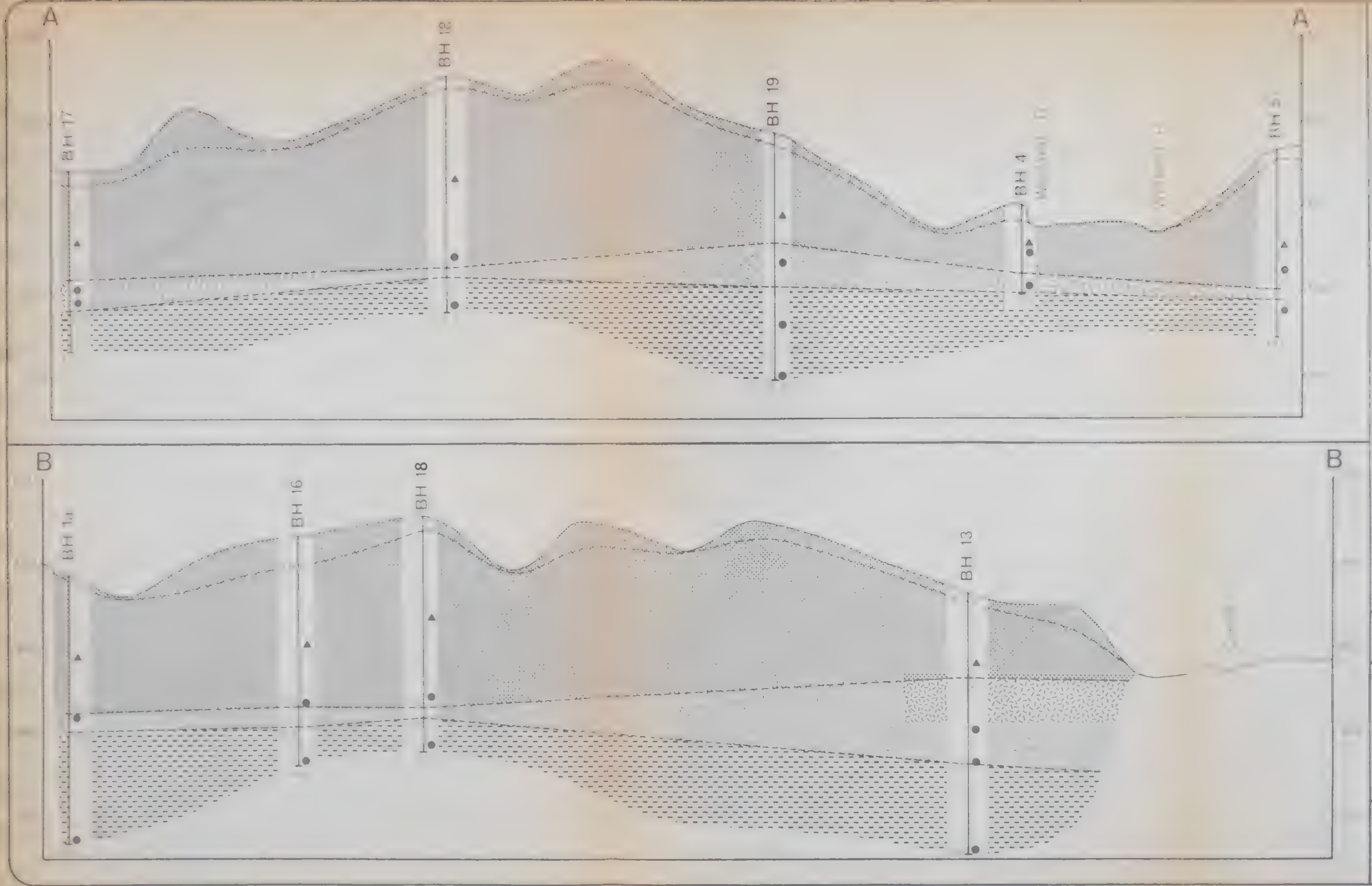
Borehole No.	Sample No.	Depth (ft.)	Unit Weight (pcf)	Water Content (%)	Porosity (%)	Permeability (cm/sec)	Direction
18	2	10	125	28	41.3	1×10^{-7}	horizontal
18	2	10	126	27	40.4	2×10^{-8}	vertical

TABLE 5

IN SITU PERMEABILITY TEST RESULTS

Borehole No.	Piezometer No.	Depth (ft.)	Permeability (cm/sec)	Comments
13	I	61.5	10^{-7} cm/sec	bedrock unit - 20' depth
15	I	55	10^{-6} cm/sec	bedrock unit - upper surf
15	II	31	10^{-7} cm/sec	lacustrine silt & clay
18	I	55	10^{-6} cm/sec	bedrock - upper surface
18	II	43.5	10^{-7} cm/sec	lacustrine silt clay

CROSS - SECTIONS



Legend

- Lacustrine Silt and Clay
- Till
- Bedrock

Gartner Lee Borehole Designation

Assumed

End of Borehole

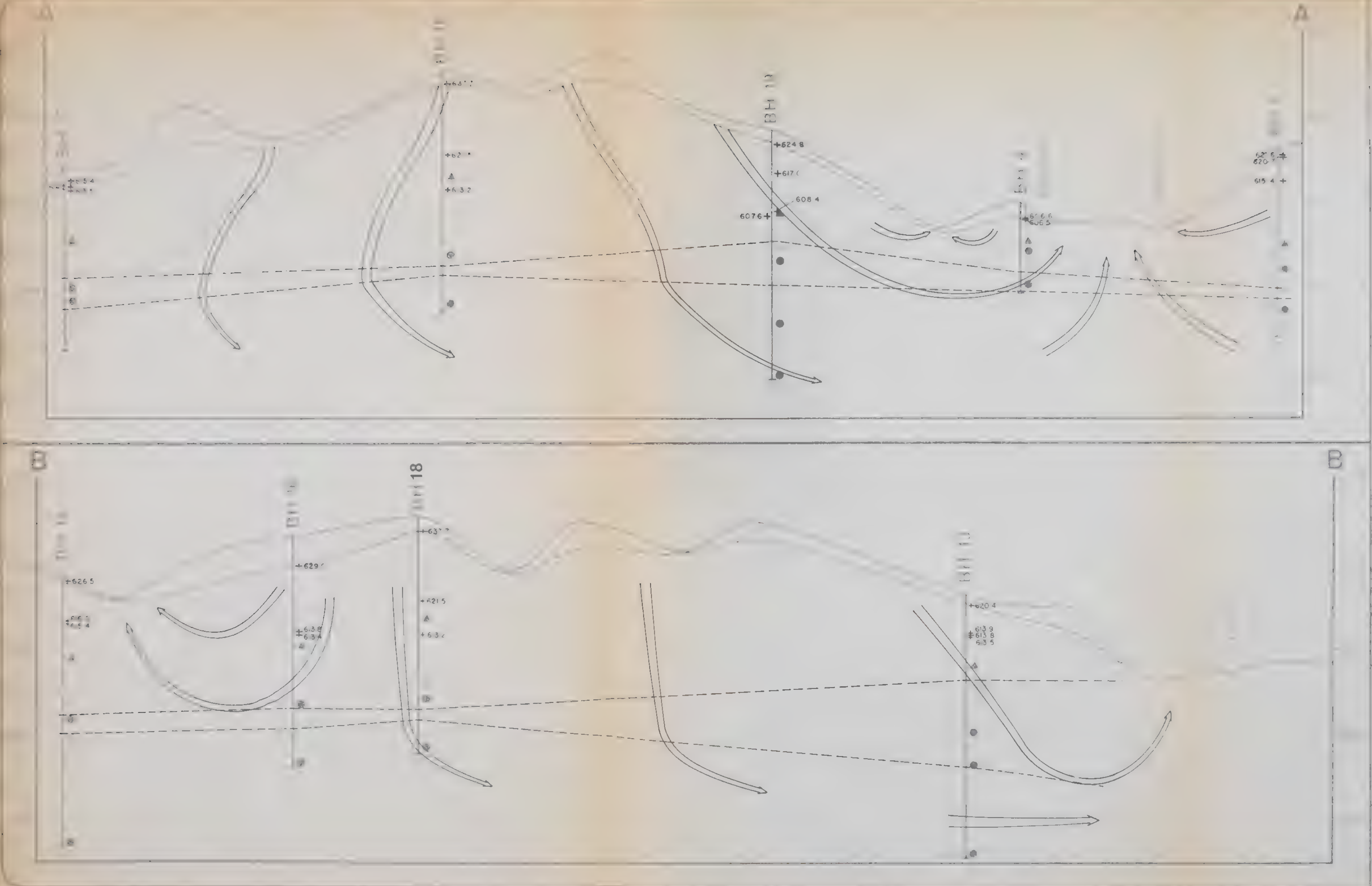
The geology has been verified at borehole location only, and may vary from that shown

Geologic Cross-Sections 7

Hydrogeological Study
Proposed
Glanbrook Sanitary Landfill Site
for
Regional Municipality of Hamilton Wentworth

Scales Horizontal
1in to 400ft
Vertical
1in to 20ft

Gartner Lee Associates Limited



Legend

Probable Ground Water Flow Direction

Ground Water Elevation (April, 1978)

Gartner Lee Borehole Designation

Assumed Ground Surface

Probable Water Table (April, 1978)

Standpipe Tip

Stratigraphic Change

Piezometer Tip

End of Borehole

Sub-Surface Ground Water Flow
Cross-Sections

8

Hydrogeological Study
Proposed
Glanbrook Sanitary Landfill Site
for
Regional Municipality of Hamilton Wentworth

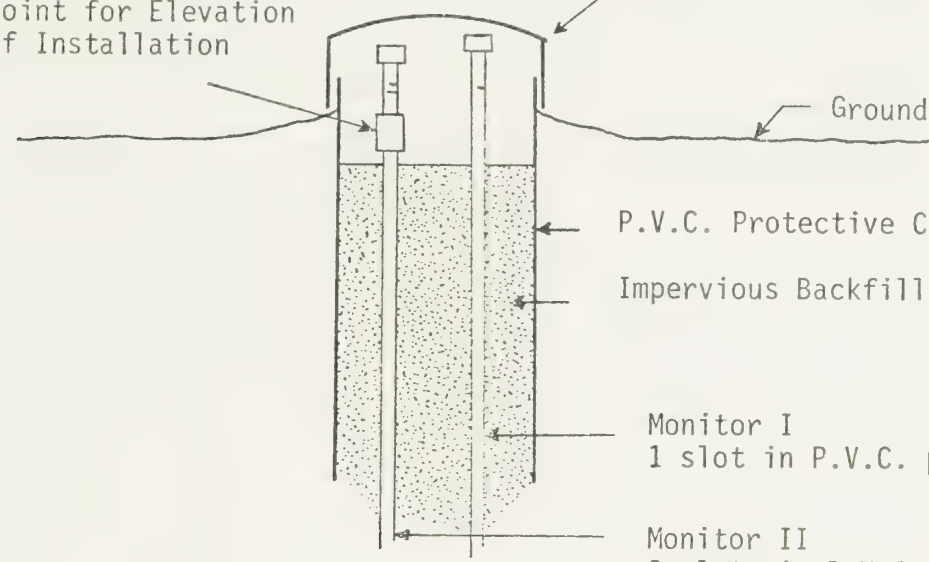
Scales: Horizontal 1in to 400ft
Vertical 1in to 20ft

PART 2

GROUND WATER DETAILS

GROUND WATER MONITOR DETAILS

GROUND WATER MONITOR DETAILS



NOTE: Variations of the typical section have been used to meet specific situations.

Typical Section

Notes: i) Standpipes consist of P.V.C. pipe slotted with a hacksaw over the bottom 3 feet of the pipe. The slotted area is wrapped with fiberglass cloth to minimize siltation. The standpipe is installed in a separate small diameter borehole and sealed with concrete immediately above the slotted zone. Standpipes are used to measure the phreatic surface.

ii) Piezometers consist of the Trow type and slotted P.V.C. pipe. The Trow type piezometer is an 18 inch long porous tube, 1½ inches in diameter and packed with fine gravel. The pipe piezometer is constructed by slotting a 2 foot length of P.V.C. pipe with a hacksaw and wrapping with fiberglass tape. Piezometers are used to measure the hydrostatic pressure.

GROUND WATER MONITOR DETAILS

BOREHOLE NO.	MONITOR				LOCATION OF TIP		LOCATION OF SEAL	
	No.	Diameter	Type	Elev.	Depth	Elev.	Depth	Elev.
1	I	1¼"	●	Destroyed	35.0'	594.2	28.5'	600.7
	II	3/4"	▲	Destroyed	25.6'	603.5	5.4'	623.7
1A	I	1¼"	●	627.3	63.9'	563.4	61.4'	565.9
	II	3/4"	●	627.3	34.5'	592.8	32.0'	595.3
	III	3/4"	▲	630.0	20.0'	610.0	17.0'	613.0
2	I	1¼"	●	623.4	26.6'	596.8	23.0'	600.4
	II	3/4"	▲	623.4	20.0'	603.4	6.3'	617.1
3	I	1¼"	●	Destroyed	34.1'	590.3	28.0'	596.4
	II	3/4"	▲	Destroyed	22.0'	602.3	7.0'	617.3
4	I	1¼"	●	609.5	20.0'	589.5	18.0'	591.5
	II	1¼"	●	609.5	12.0'	597.5	14.0'	595.5
	III	3/4"	▲	609.4	10.0'	599.4	10.0'	599.4
5	I	1¼"	●	623.0	38.5'	584.5	34.0'	589.0
	II	1¼"	●	622.9	29.0'	593.9	26.0'	596.9
	III	3/4"	▲	622.7	23.0'	599.7	1.0'	621.7
6	I	1¼"	●	615.2	34.5'	580.7	31.0'	584.2
	II	1¼"	●	615.2	24.5'	590.7	26.0'	589.2
	III	3/4"	▲	615.2	20.0'	595.2	21.0'	594.2
7	I	1¼"	●	624.3	45.4'	578.9	42.0'	582.3
	II	1¼"	●	624.3	35.5'	588.8	36.5'	587.8
	III	3/4"	▲	624.3	29.5'	594.8	32.0'	592.3
8	I	1¼"	●	615.1	53.0'	562.1	46.8'	568.3
	II	1¼"	●	614.8	35.0'	579.8	36.0'	578.8
	III	3/4"	▲	Destroyed	25.0'		30.0'	
9	I	1¼"	●	612.1	29.1'	583.0	20.0'	592.1
	II	3/4"	▲	Destroyed	13.5'	599.2	2.0'	610.7
10	I	1¼"	●	613.9	31.5'	582.4	33.0'	580.9
	II	3/4"	▲	Destroyed	15.0'		28.5'	

● - Piezometer ▲ - Standpipe

Gartner Lee Associates Limited

TABLE 6 SHEET 2

GROUND WATER MONITOR DETAILS

BOREHOLE NO.	MONITOR				LOCATION OF TIP		LOCATION OF SEAL	
	No.	Diameter	Type	Elev.	Depth	Elev.	Depth	Elev.
11	I	3/4"	●	622.3	63.0'	559.3	60.5'	561.8
	II	1/2"	●	622.3	51.8'	570.5	43.0'	579.3
	III	1¼"	●	622.3	36.0'	586.3	33.0'	589.3
	IIII	3/4"	▲	622.3	15.0'	607.3	12.0'	610.3
12	I	1¼"	●	628.2	47.0'	581.2	37.0'	591.2
	II	1¼"	●	628.2	35.5'	592.7	33.0'	595.2
	III	3/4"	▲	629.1	20.0'	609.1	17.0'	612.1
13	I	3/4"	●	622.5	61.5'	561.0	58.0'	564.5
	II	1/2"	●	622.5	40.0'	582.5	37.0'	585.5
	III	1¼"	●	622.1	33.0'	589.1	30.5'	591.6
	IIII	3/4"	▲	623.0	17.0'	606.0	14.0'	609.0
14	I	1¼"	●	636.9	64.5'	572.4	55.0'	581.9
	II	3/4"	●	636.9	50.0'	586.9	47.5'	589.4
	III	3/4"	▲	637.5	30.0'	607.5	27.0'	610.0
15	I	1¼"	●	638.7	65.0'	573.7	55.0'	583.7
	II	1¼"	●	638.7	31.0'	607.7	28.5'	610.2
	III	1/2"	▲	640.2	25.0'	615.2	22.0'	618.2
16	I	1¼"	●	636.0	53.8'	582.2	44.5'	591.5
	II	1¼"	●	636.0	39.5'	596.5	37.0'	599.0
	III	3/4"	▲	635.1	25.8'	609.3	22.8'	612.3
17	I	1¼"	●	618.8	31.5'	587.3	29.0'	589.8
	II	1¼"	●	618.8	28.5'	590.3	26.0'	592.8
	III	3/4"	▲	618.7	17.5'	601.2	14.5'	604.2
18	I	1¼"	●	641.0	55.0'	586.0	47.5'	593.5
	II	1¼"	●	641.0	43.5'	597.5	41.0'	600.0
	III	3/4"	▲	641.4	25.0'	616.4	23.0'	618.4
19	I	1/2"	●	627.9	58.3'	569.6	55.3'	572.6
	II	1/2"	●	627.9	46.0'	581.9	36.0'	591.9
	III	1¼"	●	627.7	31.5'	596.2	28.0'	599.7
	IIII	1¼"	▲	627.7	20.0'	607.7	17.0'	610.7

● - Piezometer ▲ - Standpipe

GROUND WATER MONITOR DETAILS

BOREHOLE NO.	MONITOR				LOCATION OF TIP		LOCATION OF SEAL	
	No.	Diameter	Type	Elev.	Depth	Elev.	Depth	Elev.
20	I	1¼"	●	629.6	44.5'	585.1	35.0'	594.6
	II	1¼"	●	629.6	27.5'	602.1	25.0'	604.6
	III	3/4"	▲	630.1	20.0'	610.1	17.0'	613.1

● - Piezometer ▲ - Standpipe

GROUND WATER ELEVATIONS

PROJECT 76-49 TABLE 7 SHEET 1

GROUND WATER ELEVATIONS

BOREHOLE NUMBER	MONITOR		AUG. 30 1976	SEPT 24 1976	NOV. 5 1976	MARCH 1977	JUL. 13 1977	AUG. 23 1977	FEB. 14 1978	MAR. 8 1978	APR. 3 1978	APR. 25 1978	
	No.	Type											
1	I	●	618.0	619.1	619.6	629.2	Destroyed	-	-	-	-	-	
	II	▲	625.1	625.2	625.5	629.2	Destroyed	-	-	-	-	-	
1A	I	●							615.3	612.4	619.0	615.4	
	II	●							616.2	613.0	619.3	616.0	
	III	▲							624.8	623.8	625.7	626.5	
2	I	●	616.4	616.8	617.2	623.4	N/A	617.6				621.4	
	II	▲	617.1	617.2	617.7	623.4	N/A	617.6				622.8	
3	I	●	607.4	610.9	611.6	624.4	Destroyed	-	-	-	-	-	
	II	▲	614.8	613.5	613.2	624.3	Destroyed	-	-	-	-	-	
4	I	●	596.7	601.2	603.7	609.5	604.1	604.8	604.8	604.1	605.4	606.6	
	II	●	601.5	603.4	603.6	609.5	604.3	604.3	604.8	N/A	607.0	606.5	
	III	▲	601.4	602.6	603.6	609.5	603.9	604.5	604.7	603.4	607.1	Destroyed	
5	I	●	609.1	609.6	610.2	623.0	622.6	612.8	614.1	610.5	613.9	615.4	
	II	●	611.3	611.6	612.4	621.9	612.4	611.7	621.5	612.6	613.4	621.6	
	III	▲	617.2	617.1	616.9	622.0	617.1	617.4	618.1	616.9	620.4	620.7	
6	I	●	606.6	607.1	607.4	613.2	612.1	611.4	610.4	607.4	610.2	609.9	
	II	●	606.9	607.3	607.9	610.2	608.0	608.1	609.9	597.5	610.7	611.2	
	III	▲	606.9	606.2	607.3	609.0	607.2	607.4	608.6	608.1	609.7	609.5	

● - Piezometer ▲ - Standpipe

GROUND WATER ELEVATIONS

BOREHOLE NUMBER	MONITOR No.	MONITOR Type	AUG. 30 1976	SEPT 24 1976	NOV. 5 1976	MARCH 1977	JUL. 13 1977	AUG. 23 1977	FEB. 14 1978	MAR. 8 1978	APR. 3 1978	APR. 25 1978	
7	I	●	603.4	618.8	619.5	620.2	619.8	619.3	N/A	N/A	622.5	622.7	
	II	●	619.3	618.7	619.7	620.2	620.0	619.4	N/A	N/A	622.6	623.3	
	III	▲	619.4	618.8	619.5	622.6	620.1	619.3	N/A	N/A	623.1	623.3	
8	I	●	611.9	611.6	612.4	615.1	612.2	613.1	610.7	611.9	612.1	612.6	
	II	●	610.3	608.5	608.0	614.8	614.6	614.8	613.5	610.5	610.8	613.5	
	III	▲	Destroyed	--------	--------	--------	--------	--------	--------	--------	--------	--------	
9	I	●	N/A	614.6	613.5	612.1	Flow	Flow	613.2	614.4	614.4	614.6	
	II	▲	609.7	610.2	609.7	612.7	Flow	Flow	Destroyed	--------	--------	--------	
10	I	●	612.9	612.9	612.8	613.9	613.5	612.8	N/A	N/A	N/A	613.4	
	II	▲	Destroyed	--------	--------	--------	--------	--------	--------	--------	--------	--------	
11	I	●							613.9	612.3	614.5	613.5	
	II	●							613.9	612.6	616.0	613.7	
	III	●							613.4	611.6	612.2	613.5	
	IIII	▲							615.9	615.5	617.3	618.6	
12	I	●							613.4	613.4	617.7	613.3	
	II	●							614.7	612.5	617.9	614.4	
	III	▲							618.9	616.2	620.3	623.0	

● – Piezometer ▲ – Standpipe

PROJECT 76-49

TABLE 7 SHEET 3

GROUND WATER ELEVATIONS

BOREHOLE NUMBER	MONITOR No.	MONITOR Type	AUG. 30 1976	SEPT 24 1976	NOV. 5 1976	MARCH 1977	JUL. 13 1977	AUG. 23 1977	FEB. 14 1978	MAR. 8 1978	APR. 3 1978	APR. 23 1978	
13	I	●							614.0	611.9	613.2	613.8	
	II	●							615.3	612.9	612.2	613.9	
	III	●							614.7	612.8	613.6	613.5	
	IIII	▲							615.2	618.6	619.0	620.4	
14	I	●							611.4	608.6	610.9	609.5	
	II	●							616.1	615.2	616.8	616.0	
	III	▲							627.0	626.7	628.0	627.8	
15	I	●							609.7	632.4	634.2	611.4	
	II	●							632.8	632.5	634.2	634.0	
	III	▲							636.1	N/A	636.4	Destroyed	
16	I	●							614.3	611.7	615.0	613.8	
	II	●							613.9	612.0	615.2	613.4	
	III	▲							628.1	N/A	622.8	629.0	
17	I	●							614.1	612.5	613.5	614.2	
	II	●							613.4	612.7	613.7	613.5	
	III	▲							615.7	N/A	615.5	615.4	

● - Piezometer ▲ - Standpipe

PROJECT 76-49 TABLE 7 SHEET 4

GROUND WATER ELEVATIONS

BOREHOLE NUMBER	MONITOR No.	MONITOR Type							FEB. 14 1978	MAR. 8 1978	APR. 3 1978	APR. 25 1978	
18	I	●							614.4	607.8	611.9	613.2	
	II	●							622.5	613.2	617.5	621.5	
	III	▲							636.5	635.6	637.8	637.7	
19	I	●							612.9	606.8	609.8	607.6	
	II	●							613.0	607.4	611.2	608.4	
	III	●							618.7	617.4	616.1	617.0	
	IIII	▲							621.2	622.4	625.0	624.8	
20	I	●							613.5	612.3	618.3	614.3	
	II	●							618.9	617.4	620.5	618.2	
	III	▲							625.4	624.4	625.1	625.8	

● – Piezometer ▲ – Standpipe

Gartner Lee Associates Limited

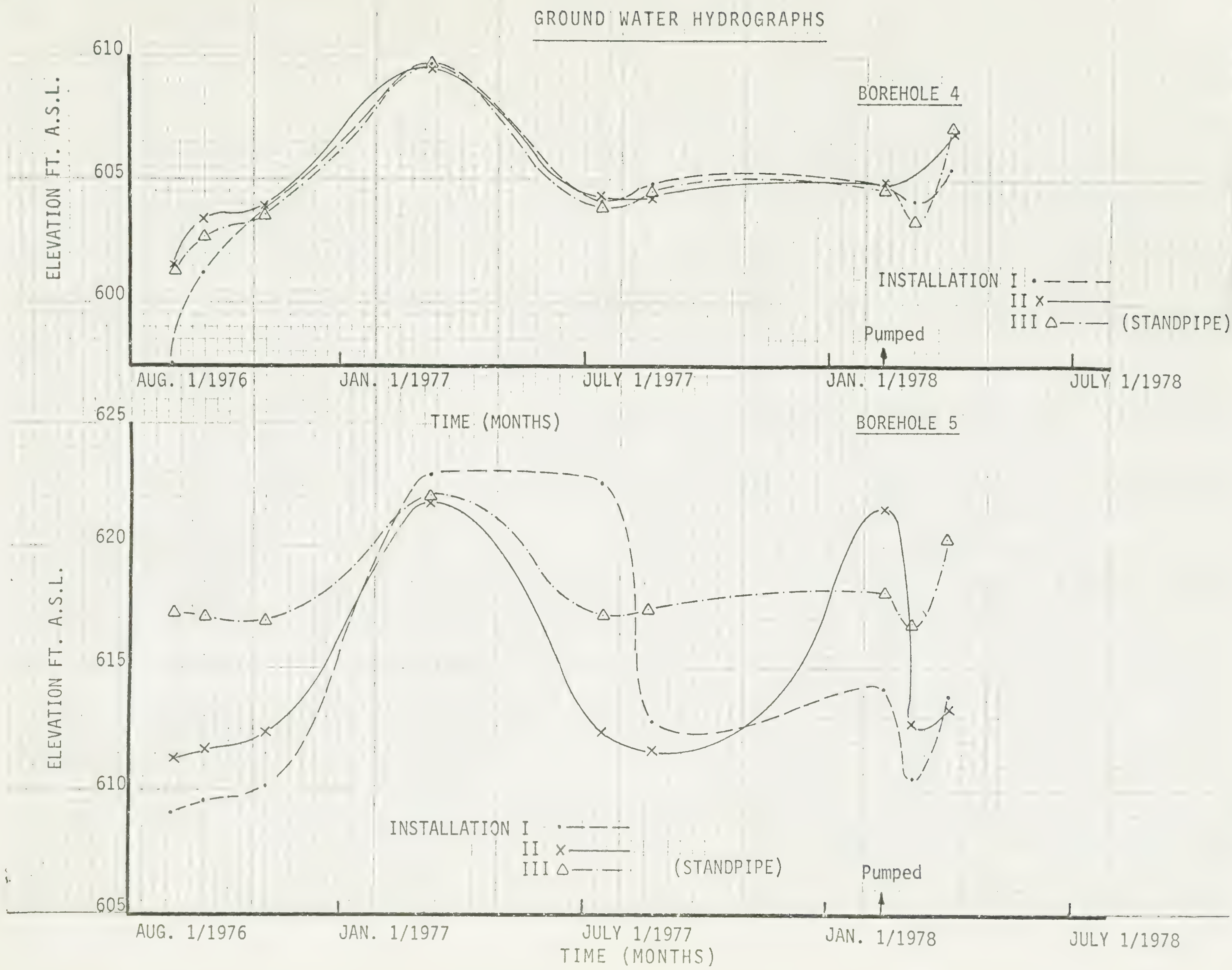

GROUND WATER HYDROGRAPHS
BOREHOLE 4
ELEVATION FT. A.S.L.
610
605
600
INSTALLATION I •
II ×
III △ (STANDPIPE)
Pumped
AUG. 1/1976
JAN. 1/1977
JULY 1/1977
JAN. 1/1978
JULY 1/1978
TIME (MONTHS)
BOREHOLE 5
625
620
615
610
605
INSTALLATION I •
II ×
III △ (STANDPIPE)
Pumped
AUG. 1/1976
JAN. 1/1977
JULY 1/1977
JAN. 1/1978
JULY 1/1978
TIME (MONTHS)

FIGURE 3.

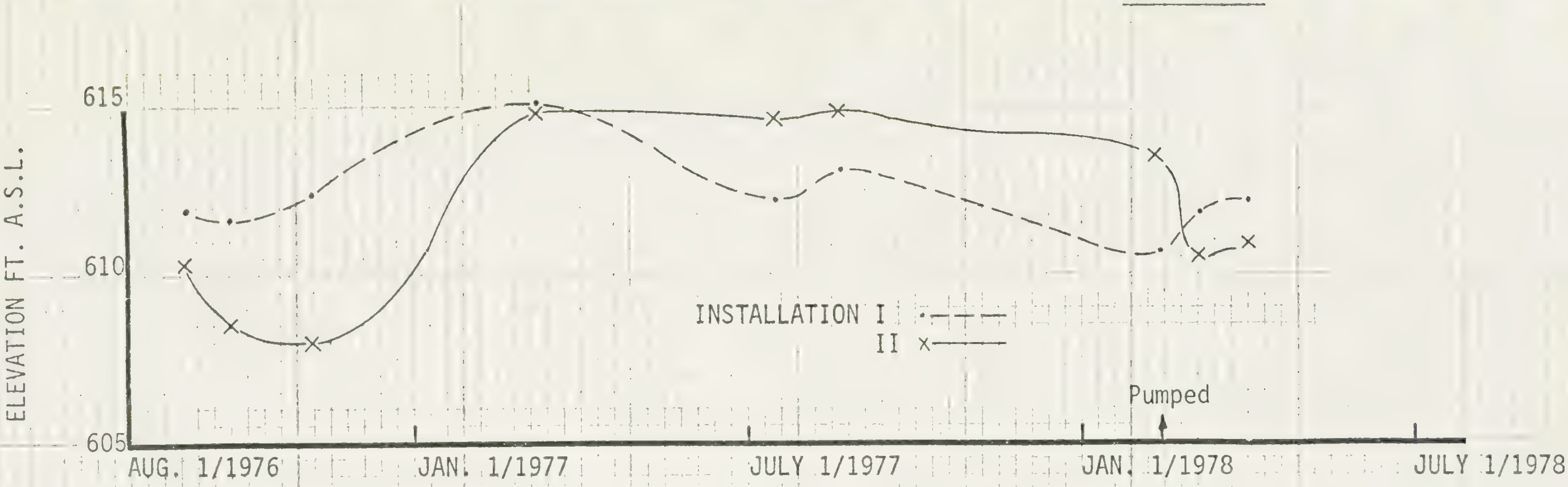
GROUND WATER HYDROGRAPH

FIGURE 4.

GROUND WATER HYDROGRAPH

FIGURE 5.

GROUND WATER HYDROGRAPHS



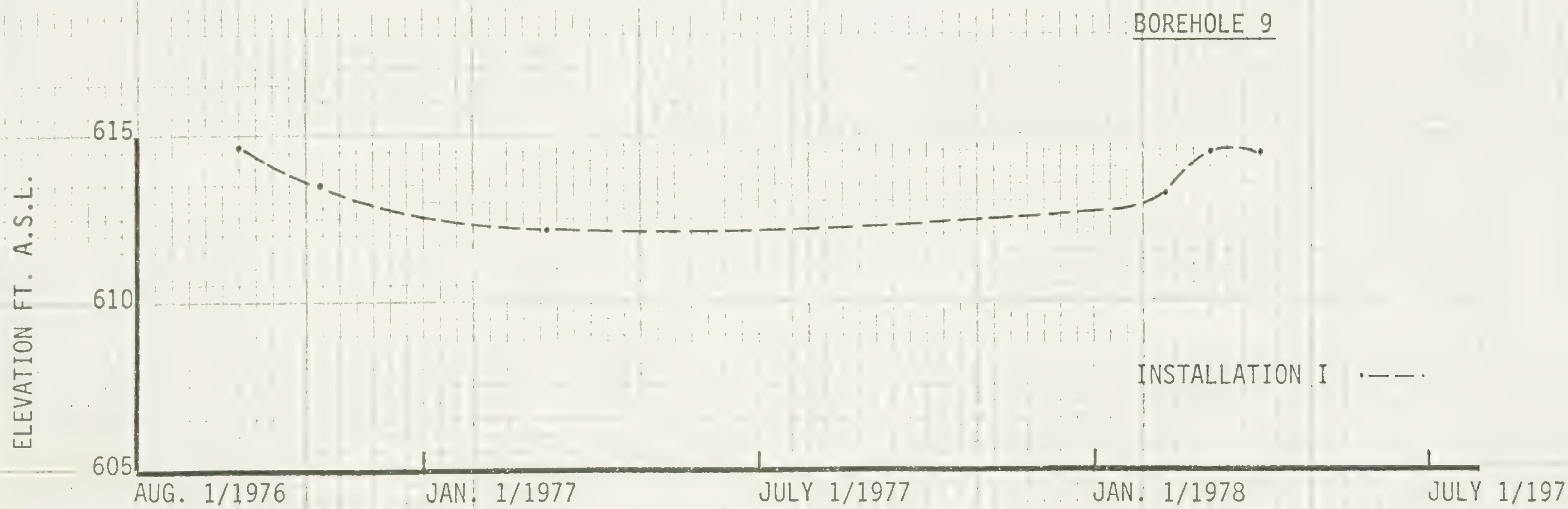


FIGURE 6.

WATER WELL DATA

Legend

●A16 Gartner Lee Survey Station

Water Well Reconnaissance Survey 9

Hydrogeological Study
Proposed Glanbrook Sanitary Landfill Site
for
Regional Municipality
of
Hamilton Wentworth

Project 76 49
Scale 1:25,000

N

Gartner Lee Associates Limited

PROJECT 76-49 WATER WELL DATA TABLE 8 SHEET 1

well no	name (owner) location	collar elev.	date	well dia.	water found	static level	pump level	pump rate	specific capacity	well use	well log
A 1 (1575)	May, Wm. a)	636	1964	6"	-	20	45	8	0-32	L	0 - 12' Brown clay 12 - 42' Blue clay 42 - 51' Limestone
	b)	-	CISTERN	-	-	-	-	-	-	D	
A 2	Smith	-	1976	6"		15	20	-	-	D	0 - 18' Brown clay 18 - 33½' Grey clay 33½' - 34' Grey fine gravel
A 3	Hanson, G.		NO INFORMATION								
A 4			NO INFORMATION								
A 5	Druery, B.	-	1946	6"	42	20	20	-	-	D&L	
A 6	Druery, B. a)	-	1946	6"	42	20	20	-	-	D&L	Drilled Well
	b)	-	-	-	-	18	-	-	-	D&L	Dug Well 40' depth
	c)	-	-	-	-	18	-	-	-	Not Used	Dug Well 40' depth
A 7			NO INFORMATION								
A 8			NO INFORMATION								
A 9	Salmon a)	-	-	12'	-	2	-	-	-	D&L	Dug Well 20' depth
	b)	-	-	12'	-	2	-	-	-	D&L	Dug Well 20' depth
(7940)	c)	640	1971	6"	64	41	45	25	6.25	-	Drilled Well (unconfirmed)
A10	Wilson, F. a)	628	1969	6"	48	24	30	30	5	D	0 - 47' Brown clay 47 - 58' Limestone
	b)	-	CISTERN	-	-	-	-	-	-	D	

PROJECT 76-49 WATER WELL DATA TABLE 8 SHEET 3

well no	name (owner) location	collar elev.	date	well dia.	water found	static level	pump level	pump rate	specific capacity	well use	well log
A19	Schuetze, H.	-	-	48"	-	5.0	-	-	-	D	Dug Well
A20 (1582)	Adamo, R.	625	1946	6"	51	20	-	-	-	D	0 - 48' Clay 48 - 50' Gravel 50 - 51' Limestone
A21	Gawley		NO INFORMATION								
A22	Kinzel, W.		1926	6"	60	6.0	-	-	-	D	
A23	Weinhardt		NO INFORMATION								

NOTES

1. The symbol '-' indicates that information was not available.
2. Abbreviations: D - Domestic
   L - Livestock

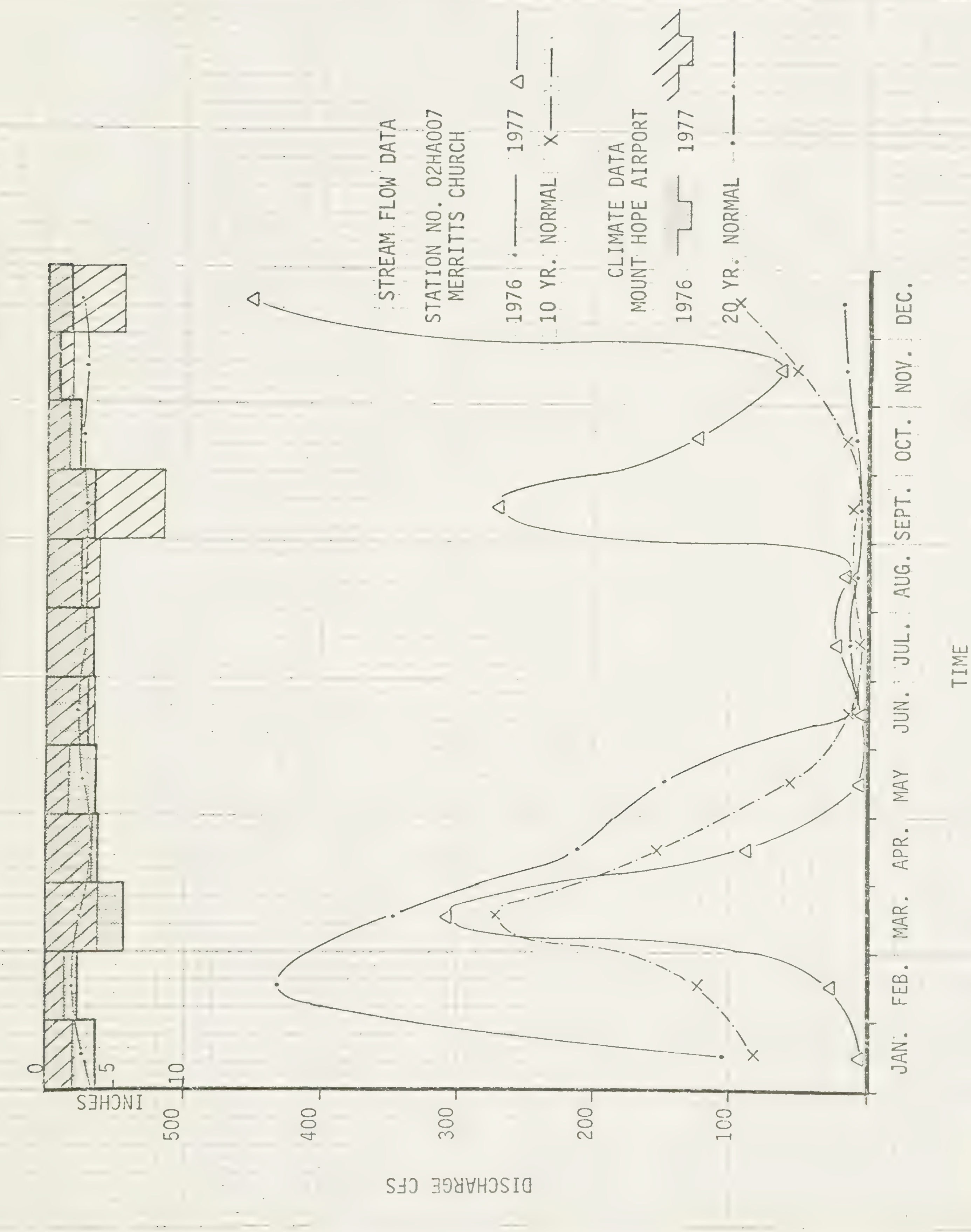
PART 3

HYDROLOGIC DETAILS

STREAM FLOW DATA

FIGURE 7.

1976, 1977 HYDROGRAPH DATA - STREAM FLOW

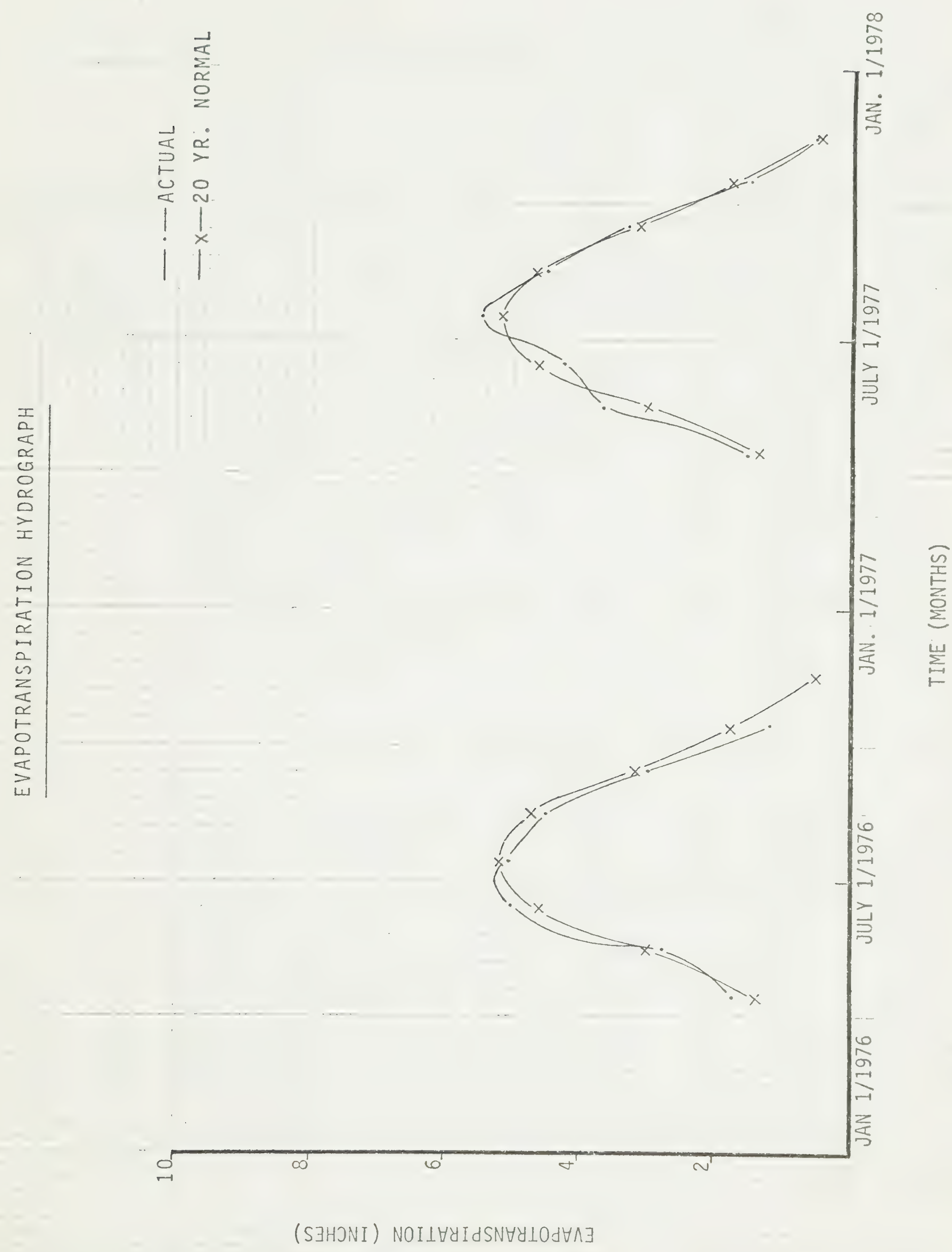


CLIMATE DATA

TEMPERATURE - PRECIPITATION

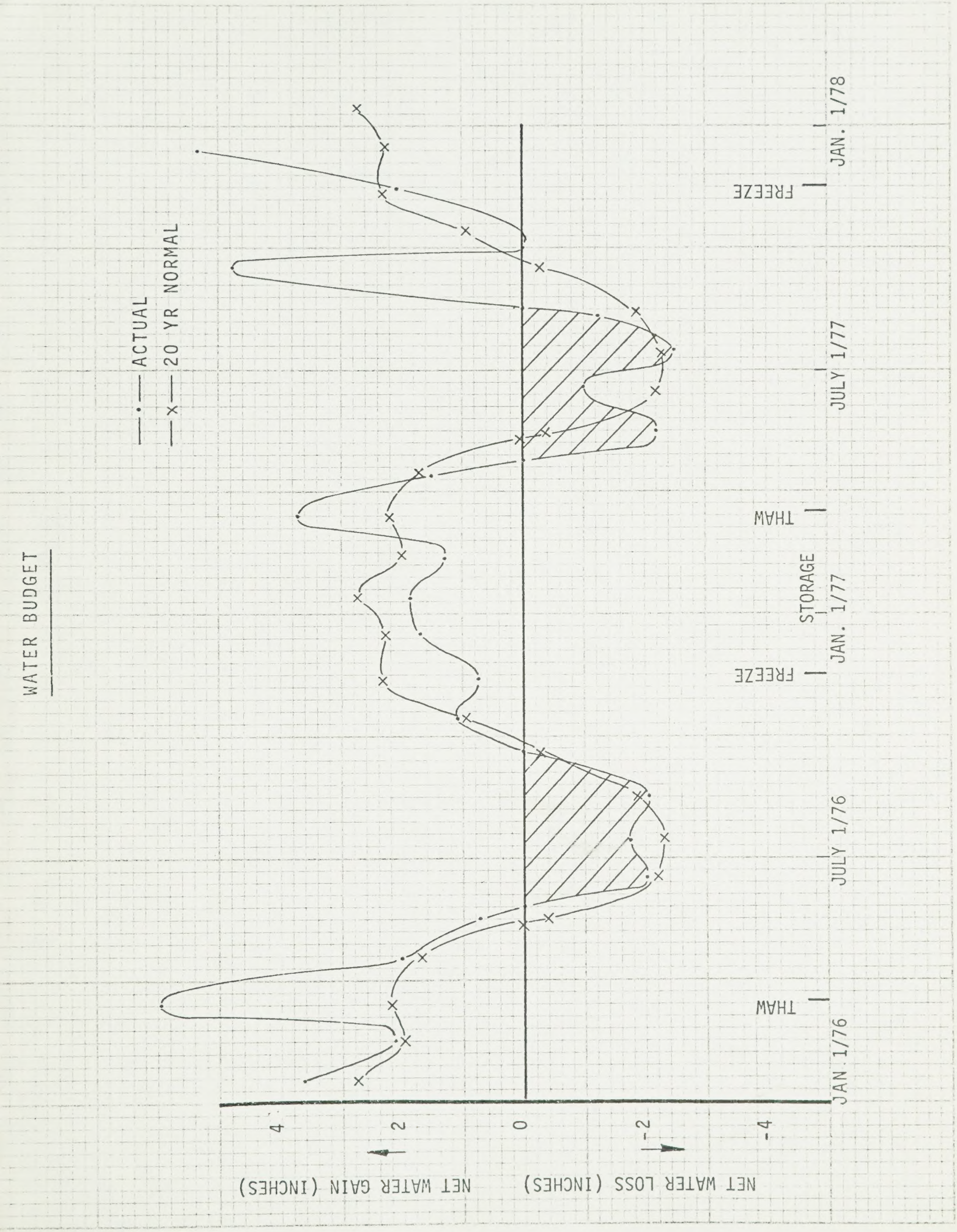
FIGURE 8.

FIGURE 9



EVAPOTRANSPIRATION HYDROGRAPH
ACTUAL
20 YR. NORMAL
10
8
6
4
2
EVAPOTRANSPIRATION (INCHES)
JAN 1/1976
JULY 1/1976
JAN. 1/1977
JULY 1/1977
JAN. 1/1978
TIME (MONTHS)

FIGURE 10.


WATER BUDGET
ACTUAL
20 YR NORMAL
NET WATER GAIN (INCHES)
NET WATER LOSS (INCHES)
4
2
0
-2
-4
JAN 1/76
THAW
JULY 1/76
FREEZE
JAN. 1/77
STORAGE
THAW
JULY 1/77
FREEZE
JAN. 1/78